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A Practical Reference Work on

CARPENTRY, BUILDING SUPERINTENDENCE, CONTRACTING, SPECIFICATIONS, ESTIMATING, BUILDING LAWS AND CODE, UNDERWRITERS' REQUIREMENTS, HEATING, VENTILATION, PIPE FITTING, PLUMBING, ARCHITECTURAL DRAWING, BLUEPRINT READING, ETC.

Prepared by a Staff of

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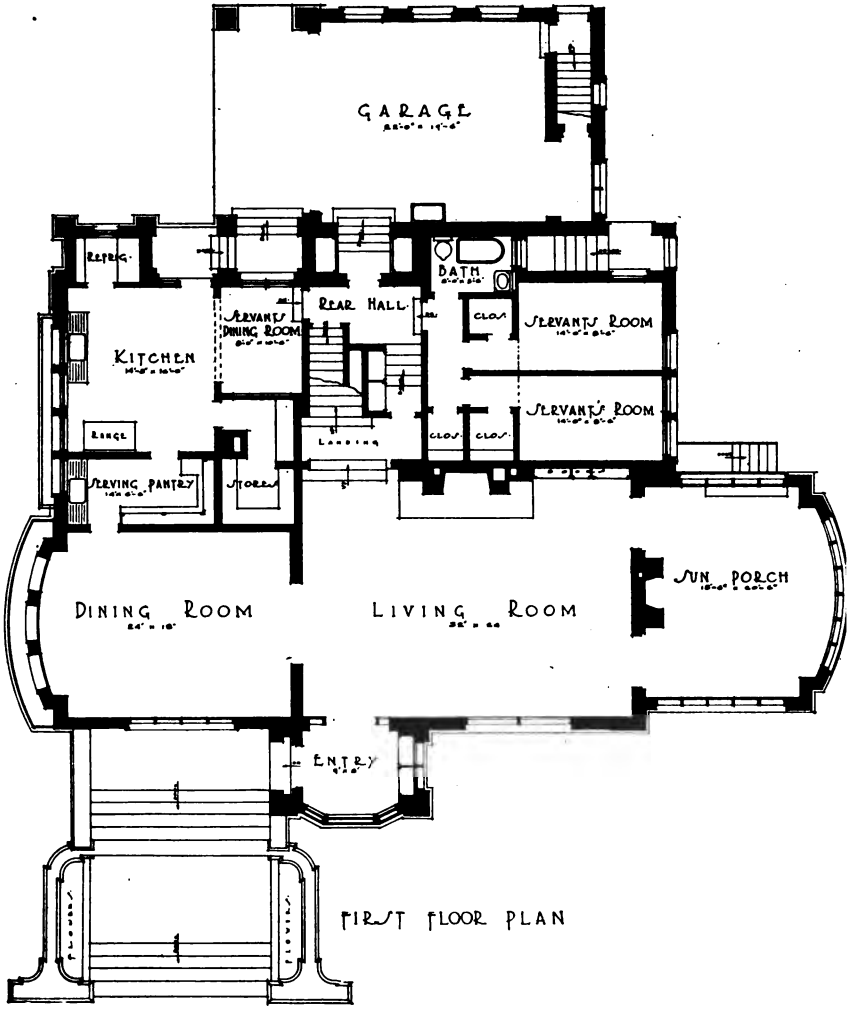

FIRST FLOOR PLAN OF H. M. STEVENSON RESIDENCE ON SHERIDAN ROAD, CHICAG
George W. Maher, Architect, Chicago
For exterior view see reverse side of page

RESIDENCE OF H. M. STEVENSON, SHERIDAN ROAD, CHICAGO
George W. Maher, Architect, Chicago
For other plans see reverse side of page

Foreword

THE building industry is today one of our most important and permanent institutions. Every new family unit must find a dwelling place, every new industry must be properly housed in order to do its work without hindrance from the weather. But with this development have come complications never dreamed of by our forefathers. In former years, every carpenter was a builder and he did very well for he confined himself to simple jobs—in fact there were none but simple jobs. There were then no complications with plumbing, gas and water fitting, heating, electric wiring, etc. There were no city ordinances to comply with, no building restrictions to be acquainted with. The laws regarding property rights, labor, etc., were simple, and the question of material was not as complicated.

¶ Today, however, all these things must be considered even if a building is to be erected in a comparatively small town. Most villages have some kind of water system, electricity and gas are almost everywhere, and the house builder demands more artistry in the design and more comforts within the home. Year by year, the practices of our best builders are becoming more standardized, more refined, and more practical. New methods, new tools, and labor-saving ideas are being evolved as new problems of construction present themselves. It therefore behooves every contractor and builder to keep in touch with the progress of the art by possessing handbooks and reference works which will show him the way.

¶ In the preparation of these volumes, the aim has been to create not merely a work which will appeal to the trained expert but one that will commend itself to the beginner and to the self-taught practical man by broadening his knowledge beyond the limits of his experience.

¶ Another point which has been considered is that, notwithstanding the fact that this is a day of specialists, every contractor and builder must be familiar with the specifications for the foundations, framing, interior work, heating, plumbing, wiring, and other specialties entering into the construction of the building. This information is presented in readable form and will be found adequate for the construction of buildings of moderate size. For the details of construction of large buildings of steel and concrete, readers are referred to our more comprehensive reference work entitled "Architecture, Carpentry, and Building" in ten volumes.

¶ The various sections of this work have been prepared especially for home study by acknowledged experts on the subjects and are as free from technical terms as possible. The importance of such practical subjects as Carpentry, Building Superintendence, Estimating, Steam and Hot-Water Fitting, Drainage and Venting, Blueprint Reading, etc., has been emphasized. The illustrations have been selected with care, and numerous tables and diagrams are introduced wherever possible. It is the hope of the publishers that this reference work will be found of distinct value in its field.

Table of Contents

VOLUME II

BLUEPRINT READING . . . *By Howard P. Fairfield*† **Page** *11

Definition of Blueprint—Process of Making Blueprints—Importance of Blueprints—What Blueprints Should Show—General Directions: Obtaining Views, Interrelation of Views, Meaning of Projection, Projection of House, Working, Dimension, and Section Lines, Drawing Sheet Sizes, Methods of Showing Large Work, Shade Lines, Line Shading, Finish Lines, Symbols, Conventions, Intersections and Irregular Surfaces, Single Picture Views—Analysis of Typical Blueprints

MECHANICAL DRAWING . . . . . *By Ervin Kenison and Edward B. Waite* **Page** 67

Instruments and Materials: Drawing Paper, Board, Thumb Tacks, Pencils, T Square, Triangles, Compasses, Dividers, Pens, Ink, Scales, Protractor, Irregular Curve, Beam Compasses—Lettering: Forming, Spacing, Inking, Style—Preliminary Line Problems: Penciling, Inking, Examination Plates—Geometrical Definitions: Lines, Angles, Surfaces, Polygons, Triangles, Quadrilaterals, Circles, Measurement of Angles, Polyhedrons, Pyramids, Cylinders, Cones, Spheres, Conic Sections, Ellipse, Parabola, Hyperbola—Geometrical Problems—Projections—Orthographic Projection. True Length of Lines, Profile Plane, Representation of Objects, Square Prism, End View a Means of Finding Height, Intersections, Planes with Cones or Cylinders, Rectangular Prism, Cone, Regular Triangular Pyramid, Truncated Circular Cylinders, Intersection of Triangular Prism and Cylinder—Isometric Projection: Isometric of a Cube, Applications of, Character of Various Isometrics—Oblique Projection—Line Shading—Lettering—Problems on Projection

ARCHITECTURAL DRAWING . . . . . *By F. A. Bourne and H. V. von Holst* **Page** 213

Instruments and Materials: Tinted Papers, Tracing Paper, Tracing Cloth—Line Drawing—Axes—Limiting Lines—Oblique Projections—Modeling Drawings—Shadows—Values—Rendering in Wash: Grading Tints, Combination of Color, Water-Color, Rendering, Sketching—Architectural Design: Method of *École des Beaux Arts*—Exhibition Drawings—Measure Work: Datum Lines, Approximations—Rubbings—Practical Problems in Design: Composition, Scale, Ornament, Design of Dwelling, Building a House, Buildings for Offices—Design of Colonial House: Basement Plan, Floor Plans, Elevations, Framing Plans, Details, Uniform Titles for Drawings

SHEET METAL WORK . . . *By William Neubecker* **Page** 335

Skylights: Bars, Condensation Gutters, Reinforcing Strips, Weight of Glass, Single-Pitch and Double-Pitch Skylights, Hip Monitor Skylight, Ventilation, Flat Extension Skylight—Roofing: Metal Roofs, Roof Mensuration, Corrugated Iron Roofing and Siding

INDEX . . . . . **Page** 337

*For page numbers, see foot of pages.

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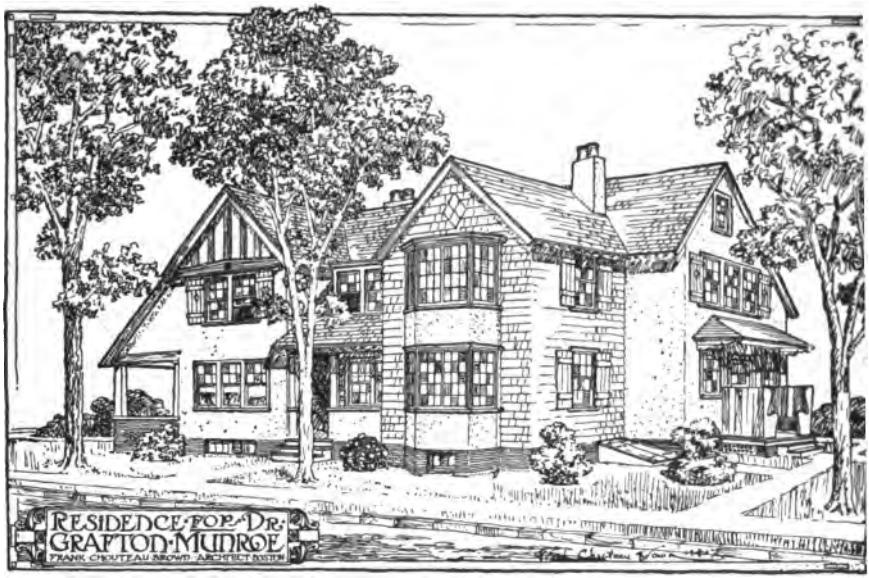

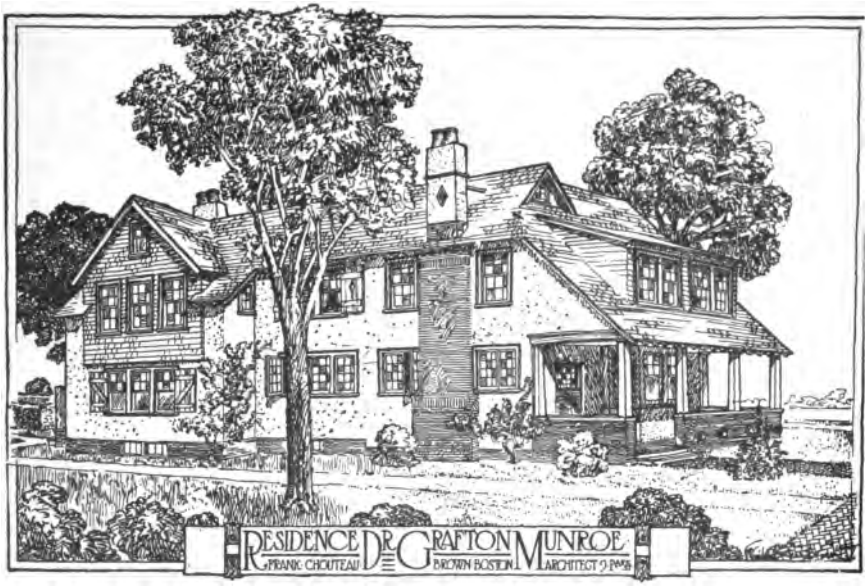

EXTERIORS OF RESIDENCE FOR DR. GRAFTON MUNROE.
Frank Chouteau Brown, Architect, Boston, Mass.

BLUEPRINT READING

INTRODUCTION

Definition of Blueprint. A blueprint as used by engineers and by workmen in the various industries is a reproduction of what is known as a *working drawing.* A working drawing, as made by the draftsman, shows by means of lines what the piece, machine, or construction is, gives the necessary working dimensions and whatever other data the workman needs to know in order to build the piece or the structure; in other words, it is the drawing by which the workman does his work and to which he looks for his information when building the structure or machining the part. However, it is essential that the working drawing itself be preserved for reference in the drafting room, and therefore a blueprint is made from the working drawing and this is what the workman uses at his machine or in the field. The lines, numerals, and letters on the original working drawing are black on a white background but these appear on the blueprint as white lines on a blue background; hence the name *blueprint.*

Process of Making Blueprints. Blueprints are contact prints; that is, the blueprint paper and the working drawing are in contact with each other while exposed to the light. Blueprint paper is a strong rather tough white paper coated with a solution which is sensitive to sunlight and turns blue when exposed to sunlight and then washed in clean water. Those firms which use large numbers of blueprints often coat their own paper. Most firms, however, buy it in the open market already coated with the prepared sensitive solution. In making a blueprint, the working drawing is laid face down on a sheet of clear glass and the blueprint paper, cut to a size slightly larger than that of the drawing, is laid on the drawing with the colored, or sensitive, side next to the drawing and by means of a clamping frame is brought and held firmly in close contact with the drawing. The holding frame is then tipped and held in a position to allow the sun or other strong light to shine squarely through the glass. The light thus

passes through those parts of the drawing on which there is no ink and effects a chemical change in the light-sensitive blue coating. The light does not shine, or pass, through the inked lines of the drawing, the lettering, or the numerals. After a short exposure to a strong light the clamps are removed and the blueprint paper is taken out of the frame and thoroughly washed in clean water. The parts upon which the strong light shone turn a rich blue color; those parts which came under the inked lines were not affected by the light rays and wash up a clean sharp white.

Importance of Blueprints. The blueprint from a properly made working drawing should contain *all* the information needed by the workman in his work and he should never ask for information until he is positive that it is not on his blueprint. It is well also for him to understand that his blueprint is an exact reproduction of a drawing on file in the drafting room and that, if he implicitly follows instructions and dimensions as given in his blueprint, he is protected in any argument which occurs over his work; in other words, if his work checks up with the blueprint he has worked from, any errors found in results are squarely up to the draftsman.

What Blueprints Should Show. A blueprint is in a sense a picture of the piece, machine, or structure which is to be made or built. This picture is made up of views; for example, front view, top view, end view, etc. (See "Mechanical Drawing," Part III, pages 73–79.) These views are made up of lines which would show clearly to the eye if the part, machine, or structure were viewed from the several positions noted; for example, a front view consists of those lines which would be clearly seen if the observer were viewing the part or machine from the front. The blueprint should also contain all the essential dimensions and indicate clearly from what surfaces they are to be taken In most cases, this is done by using a distinct arrowhead with the point resting against the line which represents the surface or the outline from which the measurement starts or from such a working line *extended;* that is, the line which represents a surface edge is lengthened to make it convenient for placing the arrowhead. Another arrowhead is placed against the line representing the surface where the measurement stops, and the two arrowheads are connected by a line called a dimension line and the given dimension is placed either in this

line or directly over it. Fig. 1 shows this. The blueprint wil probably also contain lettered directions; some surfaces are to b ground, and the word "grind" may be lettered on those surfaces others are to be polished, and on those the word "polish" may be placed.

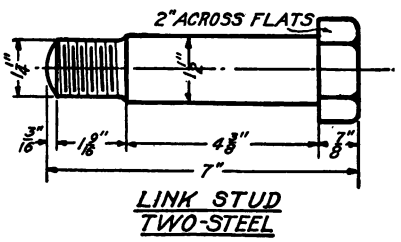

Fig. 1. Detail Drawing of Link Stud

Reading Blueprints. To be able to read a blueprint is as essential to a workman's success as to be able to read printed matter. To read blueprints readily, he must know some of the principles of making drawings. These are explained to a considerabl length and with close attention to detail in "Mechanical Drawing, Parts I, II, and III, and these books should be read most care fully. This is somewhat equivalent to learning the alphabet i learning to read printed text. The workman should first under stand that a blueprint is a record of instructions given him t read. Second, he should realize that the language used by th draftsman in making his drawing is largely a language of lines an that, unless he knows how to read lines, the instructions recorde on the blueprint are essentially in a foreign language. (Read care fully and memorize page 41, "Mechanical Drawing," Part II To read a blueprint, the first thing is to study the several view until one has a good mental picture of what he is to construc As the blueprint is a flat surface, it is necessary for the workma to use his imagination to make the lines and views lift up fro the paper. When a clear-cut mental picture has been formed, th dimensions should be studied until understood. Next all the le tered text should be read and considered. Carelessness in an one of these three respects is not to be excused.

GENERAL DIRECTIONS FOR READING BLUEPRINTS

Method of Obtaining Views. As already noted in the "Intr duction," a blueprint represents the information which the draft man is seeking to convey to the workman. It becomes necessar then for the workman to think somewhat as the draftsman think Plate I, page 14, consists of three separate outlines, or diagram

These diagrams are known as views and are obtained by projecting the outlines of the piece point by point onto an assumed plane. (Read carefully the matter under "View" and "Projection" in "Mechanical Drawing," Part III, page 73, and study Fig. 95.) In the case in hand, the paper on which the drawing is made is the plane, and as the blueprint is an exact reproduction, line for line and point for point of the original, it also can be said to be the projecting plane. As an aid in understanding what the draftsman did when he made these *views* and why they are placed on the paper as they are, let the reader imagine that with a sheet of paper he has made a *box* having all the corners and all the sides square with each other. Assume that the paper box is transparent as glass is transparent and that a piece of work might be hung inside the box centered with the sides and corners. Let us now in imagination hang various objects one at a time in this paper box centered squarely with its transparent sides through which they may readily be viewed. (Carefully study Fig. 102, "Mechanical Drawing," Part III, page 79.) If the first object selected is a perfect cube, for example, an ordinary playing dice, then, viewing this from every side of the box, it is at once evident that all the views are the same in outline. If the outline dice is drawn, with a pencil, on each side of the box, as seen through that side, we will have six outlines all of the same size and shape. If an ordinary playing domino is substituted for the dice, the views when looking into the top and the bottom of the box will be alike in outline. Those seen when looking into the right and the left ends will also be alike, as will the views seen when looking through the back and the front sides of the box. If the pencil is used as before, six outlines are shown, but instead of their being each like the other, there are three pairs of views, each pair distinctly different from the others. If these penciled views are labeled top, bottom, front, back, right end, and left end, and the paper box is cut along its corners and the paper then tacked flat on a board, we have a drawing of the piece giving six views labeled top, bottom, etc.

Instead of doing all this box work, the draftsman first trains his hands as shown in "Mechanical Drawing," Part I, pages 22–29, to use in a neat and skillful manner the various tools shown and described in pages 1–17. He also trains his hands to produce and

his mind to remember the various outlines shown in "Mechanical Drawing," Part II, pages 41–54. In addition, he must learn to imagine what he is going to make a drawing of, or, as it is termed, see the thing in space, which means form a reasonably complete *mind* picture of the piece he is to draw. In "Mechanical Drawing," Part III, pages 80–86, it is shown by what methods the draftsman avoids having to use a box with transparent sides when making a drawing; by using the tools shown in Part I, pages 1–17, in a certain conventional manner, he gets all the views he wishes on a sheet of paper tacked flat on a board.

Number of Views Needed. It will be recalled that in viewing the domino centered in the box, while we had six separate views, certain views duplicated and three views were sufficient to show clearly the outline of the piece. When drawn, some machine parts need several different views; others need only a single view. In Plate I the draftsman considered that he could get all the information the job needed on three views, namely, a front view a top view, and an end view.

Interrelation of Views. In reading Plate I and other blueprints, it will be observed that the top view and the front view center, line for line and point for point, on the same *vertical* center line, also that the front view and the end view center, line for line and point for point, on the same *horizontal* center line. Plate I, "Mechanical Drawing," Part I, page 26, shows a series of horizontal lines and a series of vertical lines, and it is explained in Part III, pages 73–86, how the vertical and horizontal reference lines work out in the drafting room. In some of the plates, it has been found necessary to readjust the different views to accommodate them to the small size plate, in violation of the rules of *third angle projection.* The student should make allowance for these discrepancies.

Meaning of Projection. To understand thoroughly what the term "projection" means, it is well to study the action of light as we view an object. Take as an example a man walking along the street. Our view of that man is made possible by the fact that light is *reflected* from his body into our eyes. This is true of all objects which we view with our eyes and we say that we *see* the man or the object. In other words, the light which is reflected, or thrown back, from the man or from the object into our eyes

gives us a view of the man or the object. If the man or the object faces toward us, we get a front view, if away from us, a rear view. While the object itself is not a source of light, it is so treated in viewing it and the light is said to be projected from the object viewed. When a view drawing is made, it is often known as a *projection.*

Projection of House. In "Mechanical Drawing," Part III, page 118, Fig. 160, is shown an isometric projection of the ordinary house. As an example of *ordinary* projection, suppose we select such a house and view it from its several sides, at a distance of not less than 100 feet from the several sides. Taking the front end first, the viewer will note that it appears as a flat wall having a rectangular outline with its top line in the shape of an inverted V. A side view gives a bottom line where the house rests on the foundation, two vertical, or upright, lines at each end of the side, a horizontal, or level, line to show the eaves, and a second horizontal line above this to represent the ridgepole. If these two views have been penciled out on a sheet of paper to some exact size, they will show what the *outline* of the house is. We can also show on these views the several doors, windows, etc., as we see them when viewing the front end and when viewing one side of the house, and if the rear end and the opposite side have the same doors, windows, etc., in exactly the same positions, the workman would be able from these two views to construct walls which would be as desired. If, however, the rear end had the doors or the windows placed differently from those on the front end or if they were not of the same size even though placed in the same manner, the workman would need a rear view to show him this fact. The same thing would hold true in respect to the sides of the house. Also, if the roof itself were broken up by windows, a top view showing their size and layout would be necessary for the workman. For convenience in making and reading the drawing, the several views are universally arranged for shop use exactly opposite the surfaces which they represent, as noted in the use of the box with transparent sides.

Lines. *Working Lines.* A study of the views in the several blueprints in this book shows at once that each view is made up of straight lines and curved lines. The straight lines, or right lines (as they are often termed by draftsmen), are used to repre-

sent the edges of plane surfaces. How such lines are drawn and the tools used for drawing them are shown in "Mechanical Drawing," Part I, pages 22–25. In the example just used, two upright straight lines a certain distance apart would be used to show the corners of the house. A circle line may show the edges of a cylinder or a hole in any surface, for example, a bolt hole or, in a house, a circular window. By using a combination of straight lines and part of a circle, the rounded end of a straight-sided bolt, for example, can be shown. Where the edges are neither straight lines nor parts of a circle, they are drawn with a special tool having an irregularly curved edge, which can be fitted to the desired line shape. (See Figs. 32 and 33, "Mechanical Drawing," Part I, pages 16 and 17.) A view, then, may consist entirely of straight lines, entirely of curved lines or of circles, or of a combination of all these. It must in any case be clearly noted that any *working* line, straight or curved, is used to show where a surface on the work changes its direction, in other words, to show the *edge of a surface.* If the object viewed is a solid piece, for example a bolt, all the working lines in the several views are solid and continuous straight or curved lines. If the work has holes through it or has hollow places hidden inside it, the lines which show the hidden edges are drawn as dots and the line is termed a dotted line. (See Fig. 110, "Mechanical Drawing," Part III, page 84.) In studying a blueprint then, it will be understood that the dotted lines in a view represent surfaces and edges which are hidden from the viewer's sight when the object is viewed from the side shown In the case of the bolt, Fig. 1, a view of the head end would show the body of the bolt as a dotted circle. In a blueprint of the house, the wall timbers, partitions, etc., which are not seen from the outside, would be shown as dotted lines.

Dimension Lines. While the house outlines as they now stand give a general idea of how its exterior would look, they do not show its size or the sizes of the several doors, windows, trim, etc To give this information, use is made of *dimension* lines drawn between points on the lines which make up the several views To indicate the place where the measurement is to start and the point where it must stop, each end of a dimension line has a neat arrowhead, the point of which just touches the line at which the

measurement starts or stops. Somewhere in the length of a dimension line are placed the numerals which give the exact measurement of the work as indicated by the arrow points. Dimension lines usually show on the blueprint much thinner than the lines which make up the views. This fact and the fact that at their ends are prominently placed neat arrowheads render it easy to avoid confusing them with the working lines of the blueprint.

In case a dimension line cannot readily be placed on the view, the working lines may be lengthened, or extended, a short distance from the view and the dimension line can then be drawn between the extended lines with the points of the arrowheads resting exactly against the extended lines. The end of an *extension* line, as it is called, should never quite touch the working line which it extends.

Section Lines. In addition to the working lines and the dimension lines on the blueprint views, the workman will, in some cases, find a series of parallel lines drawn closely together at an angle to the working lines of the view. These are known as *section* lines and are used by the draftsman to tell the workman that the part of the view covered by such lines is as if the work had been cut through and a portion removed. (Plate I, Fig. 3, "Mechanical Drawing," Part I, page 26, shows an example of section lines.) Sections open up the interior of an object or a combination of working parts, for example, the headstock of a lathe, and give a clear view of the inside. To use a homely illustration, the draftsman seeks the same effect as the grocer does when he cuts a melon in halves for the customer's inspection. A view so drawn is said to be *sectioned;* hence the term section lines. In the case of the lathe headstock, some of its parts may be of cast iron, some of bronze, some of steel, etc. To show which parts are of cast iron, of steel, or of bronze, the draftsman makes use of various arrangements of section lines, each arrangement showing a different material. In Plate III, "Mechanical Drawing," Part I, page 35, are shown and named the common arrangements of lines to show sections of different materials, viz, metals, wood, brick, concrete, etc. The workman should study those common to his work.

Drawing Sheet Sizes. In "Mechanical Drawing," Part I, page 2, is given a list of sizes of drawing sheets. While different shops may use different sizes for their blueprints, as a rule each

shop has some regular system of sizes. A common system for machine shops makes the largest regular sheet 24″×36″ and lists it size A. Such a sheet will fold and cut to give two B sheets 18″×24″. Continuing the folding and cutting gives a C size 12″×18″; a D size 9″×12″; and an E size 6″×9″. A machine shop blueprint is usually trimmed to one of these sizes.

Methods of Showing Large Work. *Reducing Scale of Drawing.* Several methods are used to make it possible to show a view of large work on a small sheet of paper. The view is often made a reduced size, which is usually spoken of as making it to a *reduced scale.* The term "scale" in such a case means that the length of the working lines in the blueprint views has a definite proportion to that of the actual lines of the work itself; for example, if the circles which represented the rim of a 24-inch pulley were drawn in a view as 12-inch circles, the view would be one-half size, or to one-half scale. If the circles were made 6 inches in diameter, the view would be to one-quarter scale. While in these cases the dimension lines would be, respectively, 12 inches or 6 inches in length from arrow point to arrow point, the dimension figures would read the exact size, 24 inches. For the reason that a blueprint view on a reduced scale does not give the average workman a good *size* picture of the work, it is customary to have the views show the work to exact, or full, size whenever it is practicable to do so. Such a view is known as a full-size view, or a full-scale view. The common machine shop *view scales* are one-eighth, one-quarter, one-half, three-quarters, and full size. Another way of expressing view scales is in inches to the foot; for example, a one-half scale is 6 inches to 1 foot and a full scale is 12 inches to 1 foot.

Showing Parts of Work. Another way of getting a view of a comparatively large piece of work into a small space on a blueprint is to show only a part of the work in the view. In the case of the pulley just mentioned, if the blueprint view showed one-quarter or one-half of the entire pulley, the average workman would be able to get all the directions necessary from the view to complete the work.

Breaking the Piece. Yet another way by which the space utilized to represent a piece of work in blueprint views can be lessened is what is known as breaking the piece. To illustrate, use is

made of the front view of a long bolt or shaft of relatively small diameter. If such a piece were shown full scale, its working length lines might reach the entire length of the blueprint or even farther. If the body of the bolt or shaft is of uniform size and shape, it is sufficient to show a portion of the body near the head and a portion near the threaded, or opposite, end, and the portions shown may be brought close up to each other and thus little space used for the view. When analyzing the several blueprints reproduced in the following pages, the ways in which space is utilized in representing the parts of the work will be noted.

Shade Lines. It must be admitted that the average blueprint view of a piece of work is a rather flat and dead thing and that some imagination on the part of the workman is needed to give it life and to make it lift up from the paper and really have form and substance. Fortunately for the machine shop workman who is just learning to read blueprints, much of his work comes to him roughly in the form in which he is to finish it. This is especially so when he is finishing ordinary castings. There are several methods used at times to give the blueprint views more "life". One much used method is to make certain of the working lines of increased thickness to represent a shaded portion. These heavier working lines are known as *shade* lines and aid somewhat in making the view stand, or lift, up from the paper. Such shade lines are used to a lesser extent now than formerly, as the workman is supposed to use his imagination when reading blueprint views.

Line Shading. The term *shade lines* should never be confused with the term *line shading* which refers to a decidedly different use of lines. Line shading as commonly used consists of a series of lines placed on the view within its working lines and arranged in such a manner as to give a picture effect to the view. In "Mechanical Drawing," Part III, pages 126 and 127, are shown a variety of objects which have been line shaded. Comparison of these illustrations with Figs. 78, 81, and 84, "Mechanical Drawing," Part II, pages 49 and 50, clearly shows what line shading does to liven up a view. As is the case with shade lines, line shading is used less in machine shop drawings than it formerly was.

Finish Lines. Another line used in blueprint views is sometimes termed a *finish* line. Such a line is usually broken up into

dashes and dots and is then known as a *dashed* line. It is placed on the view close to a working line to indicate that the surface represented by the working line is to be finished. Dashed lines are now little used for this purpose because of the chance of their being confused with dotted lines used to represent hidden surfaces and edges, and other methods of indicating finished surfaces are popular. Brown & Sharpe practice is to use a red pencil to draw a full red line on the blueprint views close beside all working lines which represent finished surfaces. A common method of indicating finish is to place a letter *f* across all working lines which represent finished surfaces.

Symbols Used. There are a number of words which often appear on blueprint views, each conveying certain information, and the workman must be familiar with the more commonly used ones to read his blueprint readily. The word "ream" near a hole shown in the view means that the hole is to be finished by reaming it; the word "tap", if so placed, indicates that the hole is to be tapped. The terms which the workman is most likely to find on his blueprint views are ream, tap, grind, polish, scrape, frost, taper, crown, and drill. He will also often note the letters *F.A.O.* near certain views; when so found, they denote that the piece of work is to be finished all over and the letter *f* is left off the working lines. It is also common machine shop practice to place on the blueprint the name of the piece of work, the number wanted, and the material to be used, all neatly lettered. The several materials used in the construction of machinery are usually indicated by their initials, for example, *M.S.* for machinery steel. To read blueprints easily and accurately, the workman should learn the symbols used, the more common of which are given and defined in the following tabulation:

F.A.O.	finished all over	C.I.	cast iron
f.	finished surface	S.C.	steel casting
RAD.	radius	Bz.	bronze
DIAM.	diameter	C.R.S.	cold rolled steel
R.H.	right hand	T.S.	tool steel
L.H.	left hand	O.H.S.	open-hearth steel
P.R.	piston rod	W.I.	wrought iron
P. Tap.	pipe tap	M.S.	machinery steel
CTRS.	centers		

Special notes neatly lettered are often placed on the blueprint and these notes should always be read carefully. In "Mechanical Drawing," Part I, pages 17–21, and Part III, pages 128–134, are shown examples of lettering. Each and every dimension line should have in clear distinct figures, either on the line or in a break in the line, the exact dimension which the dimension line represents. Dimension figures should be clear, distinct, and easily found and read. (Study Plate I, Fig. 4, "Mechanical Drawing," Part I, page 26.) Certain working variations in dimensions are allowable in all work. These are termed *tolerances* and should be given on the blueprint. They are usually preceded by the sign ± and are placed near or follow the given dimension. If the tolerances are not to be found, the workman must learn what the practice of the shop is in regard to this point.

Conventions Used. Certain conventions, as they are called, are often to be found on blueprints. Take screw threads as an example; they are seldom shown on a blueprint as actual threads but are *indicated* by an arrangment of parallel lines across the surface meant to be threaded, Fig. 1, page 3, and a note is usually lettered on or near the threaded surface giving the number of threads per inch and the form of the threads. Gear teeth are seldom shown on a blueprint; a lettered note is used instead to state the number of teeth in the gear and whether they are involute, cycloidal, or otherwise.

Intersections and Irregular Surfaces. While, in most cases, the workman can get the needed information from a sufficient number of views of the ordinary method of projection, this is not always true where two surfaces meet at an angle, especially if they meet or intersect at other than a right angle. As an example of such a case, take the spout of an ordinary tin coffee pot where it joins the body of the pot. In uniting the two, it is necessary to know just what the shape of the hole should be and its size; also, in making up the pot body and the spout body, each of which is usually tapered, it is necessary to know the exact shapes and sizes to which the sheet tin must be cut. All sheet-metal work is full of such problems, as well as work in leather, for example, shoe tops, bags, etc. To obtain the desired forms of the holes and the body of a sheet-metal object, it is in effect cut open and flattened

out as if it were a sheet of paper. The methods by which such problems are solved are very clearly shown in "Mechanical Drawing," Part III, under the headings "Intersections," pages 98–106, and "Development of Surfaces," pages 106–113. While the workman's blueprint should show the already developed surface, or pattern, he will better understand his job if he knows how such a pattern is made.

Single Picture Views. The practice in some shops is to furnish the workman with a small blueprint which has a single view of the piece he is to work on. These sketches can be made by the use of the regular draftsman's tools or, given sufficient artist's skill, may be made free hand. The excellent examples of such sketches given in Plates XXIX, XXX, and XXXI were, in the original, entirely free hand. Where one view is sufficient to show an object in its true shape, it must show the object tipped and turned into such a position as to give a picture view. The sketch artist views the object from a variety of angles, finally decides which view best shows the piece, and makes that the blueprint view for the workman. In "Mechanical Drawing," Part III, pages 113–125, the methods used to obtain these single picture views are described and illustrated.

Importance of Careful Study. The careful reader of the preceding text must now be impressed with the need of *knowing* things. The way to know a thing is to study it, just as a child studies his book when learning to read. The child first learns the simpler words, how they look, what letters of the alphabet are used in spelling them, how the words are pronounced, etc. Anyone who is willing to study this text and "Mechanical Drawing," Parts I, II, and III can learn how to read ordinary blueprints readily. To assist the reader of this text in doing this, a variety of simple blueprints have been selected for analysis. Although they by no means cover all classes of work, nevertheless, they have been selected from a large number as being the more typical of their kind. Carefully study each blueprint as well as the text, for, in the first place, you will become acquainted with good practice as carried out by several well-known firms and, in the second place, you will, by this thorough analysis, train yourself to see in any blueprint everything that was intended to be brought out.

ANALYSIS OF TYPICAL BLUEPRINTS

PLATE I

SADDLE NUT

It is evident that Plate I shows three views of a saddle nut. Before starting to read the views, the workman should read the lettered data at the top of the blueprint. From this he gets the name of the piece he is to make, "saddle nut," the number required, "one, on a single machine," the name of the machine to which the piece belongs, "5-foot boring mill," and the piece number, "14049." He next reads the lettered data at the lower edge of the blueprint and learns what material he has to work on, in this case, bronze. If this plan has been followed out, the workman now knows that he is to make a certain number of bronze saddle nuts, each of which is a part of a 5-foot boring mill.

The several views are a front view, a right end view, and a bottom view. The front view shows the piece as it would look when set on its flat base on the bench, with its long side toward the viewer. The right end view shows the piece as it would appear if set on the bench as before, but so placed that the right end would face the viewer as he stood at the bench. The remaining view shows the bottom, or base, of the piece as it would appear if the workman picked the piece up from its first position on the bench, held it above his head, and looked up at its bottom side. As both ends of the saddle nut are alike, no left end view is necessary; and as nothing is to be done to its upper, or top, surface or to its rear side, neither a top nor a rear view is necessary.

The dotted lines through the front and the bottom views show that there is a hole through the length of the work and the right end view shows that the hole is circular in shape. As the dotted lines through the front and the bottom are double lines exactly centered with the center lines of these two views and as the right end view shows a full-line circle and a dotted-line circle, something more than these lines are needed to tell us just what this hole is. Between the front view and the right end view are certain notes nicely lettered. They state that the hole has a left-hand square thread, four threads to the inch through its length,

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make everything clear as to what the hole is, and explain the name "nut" given to the piece in the title.

Near the base of the front and the right end views are certain other dotted lines which, of course, represent hidden surfaces or holes. When we look at the bottom view, it is easily seen that these are round holes. By reading the notes placed at the right of this view and by following the arrows, we learn that two of these holes are to be made to fit a No. 5 taper pin and that the two larger ones are to be drilled and tapped for a $\frac{3}{4}$-inch screw. This view also shows that there is a screw hole and a pin hole in each end of the piece and that the screw and the pin holes are placed in corners diagonally across from each other. It can also be seen by reference to the several views that the screw holes and the pin holes are placed on the same center lines. If the workman is used to general machine construction, he will know that the screw holes are for the bolts which are to hold the saddle nut to the saddle and that the pin holes are for the taper pins which locate and hold the nut to an exact position. The bottom view shows by dimension lines placed just above the view that the holes are to be placed 3 inches from each other along the length of the piece and $\frac{3}{4}$ inch in from the edges of the base. The end view shows by dimension lines placed just below the view that along the width of the piece the holes are 2 inches apart and $\frac{3}{4}$ inch in from the sides. The workman should understand that when the dimension lines are shown in this manner, the *center-to-center* distance is the more important one. In this case, the 2-inch and the 3-inch dimensions are of more importance that the $\frac{3}{4}$-inch dimensions, these latter being probably given to inform the workman that the holes must be symmetrical with the base of the nut.

Attention is called to the placing of the dimension lines between or at the side of the views and to the fact that the arrow points touch extension lines drawn to nearly touch the surface lines. Dimension lines placed between the front view and the bottom view show that the saddle nut is $4\frac{3}{4}$ inches long over all and that the over-all length of the base is $4\frac{1}{2}$ inches. Dimension lines placed just below the right end view show that the base of the nut is $3\frac{1}{2}$ inches wide over all. A dimension line placed just above the end view shows that the rounded part of the

nut is 3 inches. While reading the over-all dimensions, for example, the $4\frac{3}{4}$-inch, the $3\frac{1}{2}$-inch, and the 3-inch dimensions, the workman should at the same time see whether or not his castings measure up fairly close to these dimensions with finish allowances.

Attention is called to the fact that all the dimensions are given either in whole numbers or in whole numbers and common fractions, with the exception of the dimension for the bore of the hole, which has added to it the decimal 0.003. This would indicate that the various dimensions given, with this one exception, are not of exceptional importance, or that the workman will be furnished with a special gage, or that the work will be jigged.

In this blueprint, it will be noted that the surfaces to be finished are indicated by the letter *f* placed on the working surface lines. As thus indicated, the base of the nut, the right-hand end, and the hole through the nut are to be finished.

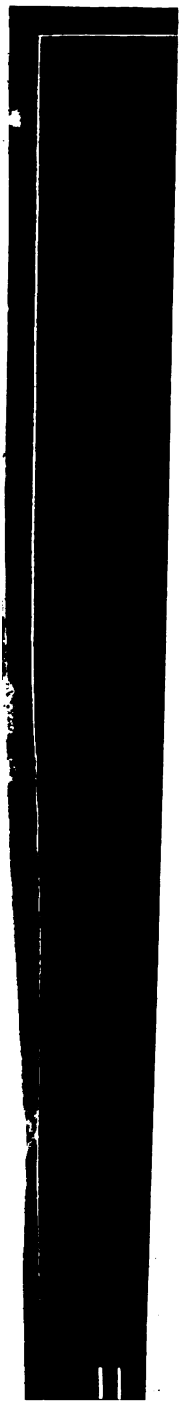
PLATE II

BACK CLUTCH PINION

The lettered data at the upper edge of Plate II informs us that the piece is a back clutch pinion for a 5-foot boring mill and that one is required on each boring mill. Lettered data also tells us that the material is machinery steel and that the rough stock is $5\frac{1}{8}$ inches in diameter and $4\frac{1}{8}$ inches long.

The views given are a front view and a left end view. As the work is round with a plain squared-up right end, two views, as shown, are sufficient for the workman to understand what the piece is as well as to get all his dimensions. As an aid in reading the blueprint, the front view shows the piece as if it had been cut in halves through its length. The parts of this view which show where the cutting is made in solid stock are cross-lined at an angle of 45 degrees with the working lines. Referring to "Mechanical Drawing," Part I, page 35, it is seen that the cross-section lines are arranged to show that, as previously stated, the material is machinery steel.

As the first machine operation on this piece of work is that of getting a hole chucked through its axis, or length, the workman will naturally read his drawing for the size of the hole. At the right hand of the front view we find a dimension line with the



arrow points touching the diameter lines of the hole extended, as explained in "General Directions for Reading Blueprints." The figures placed in the dimension line inform us that the hole is to be made $2\frac{3}{4}$ inches, and as the left end view shows a central circle, the hole is a round one. The word "ream" placed on the dimension line to the right of the dimension figures shows that the hole is to be drilled sufficiently small to permit it being reamed to its exact figured size. This dimension, as well as all the other dimensions, in the original blueprint, read two times the actual distance between the arrow points as shown on the views. The views in the original blueprint are then one-half the size of the actual piece of work and are drawn to one-half scale, in other words, 6 inches on a view represents 12 inches on the actual work.

The next two machine operations on this piece are to square the ends to the over-all length and to turn and finish it to the exact diameter. By following the end extension lines upward, we find at their upper ends a single dimension line having arrowheads with their points touching the extension lines. By reading the numeral placed in the line, it is found that the over-all length is 4 inches. Thus far this blueprint is very easily read.

Before starting work on the diameter, the views and the lettered text must be more carefully read. The name of the piece, "back clutch pinion," and a study of the views show it to be a gear with a clutch on its left-hand end.

Following out the extension lines to the left and to the right of the front view, which represent the several working diameters, we learn that the surface where the gear teeth of the pinion are to be cut is 5 inches in diameter. By following the upward extension lines, it is seen that the right-hand ends of the teeth do not start at the exact end of the stock but $\frac{1}{4}$ inch to the left of this. The extension lines also show by proper dimension lines that the faces of the teeth are to be $2\frac{1}{4}$ inches long. In this same view, the upward extension lines and dimension lines show that the remaining length of the piece from the left-hand end of the pinion teeth is $1\frac{1}{2}$ inches. Following the diameter extension lines to the left, we learn that the diameter of this part of the work is $4\frac{3}{4}$ inches.

A further study of the *left* end of the *front view* and of the *left end view* will show that the inner diameters of the clutch teeth are

counterbored out to $3\frac{1}{8}$ inches with a depth of $\frac{1}{2}$ inch. The right-hand end of the work is turned into the form of a hub having, according to the dimension line near that end, a small diameter of $3\frac{7}{8}$ inches but curving up into a fillet. Both views show that there is a tapped hole through one side of the piece, and the lettered data placed just below the front view tells us that the hole is to be drilled with a $\frac{5}{16}$-inch drill and tapped with a $\frac{3}{8}$-inch tap. Both views show the clutch teeth.

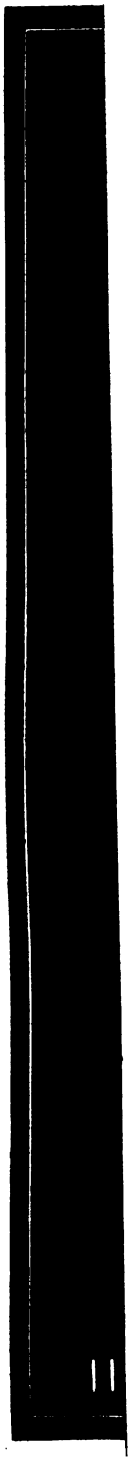
In the left end of the front view, extension lines carried upward have dimension arrowheads and numerals which show that the clutch teeth are to be cut $\frac{1}{2}$ inch deep. The left end view shows the general form of the clutch teeth. A lettered note just below this view states that there are to be five teeth and that the spaces between the teeth are to be $\frac{1}{8}$ inch wider than the teeth themselves. This indicates that the teeth in the mating part of the clutch and the teeth in the piece shown in this blueprint will, when in mesh, clear each other by a distance of $\frac{1}{8}$ inch. A lettered note placed just below the front view informs us that the gear teeth are twenty-three in number and that a five-pitch cutter is to be used in cutting them.

No finish *f* marks are placed on the various working lines in either view, but a lettered note *F.A.O.* tells us that the piece is to be finished all over. Two dotted lines on the front view indicate that there are hidden surfaces—in this case, the right-hand and the left-hand ends of the gear teeth of the pinion. If this text has been carefully studied, the reader will readily understand that Plate II really represents two pieces of work made solid in one piece of stock, namely, a toothed clutch and a pinion gear.

PLATE III

DOWN-FEED WORM WHEEL

In reading Plates I and II, it will have been noted that in Plate I three views were needed to show the workman all he needed, while in Plate II two views were sufficient. In Plate III a single view shows all that is needed to build this piece of work completely. The data on the upper edge of the blueprint states that the piece represented is a down-feed worm wheel for the right-hand head of a 5-foot boring mill and that one is required. The



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data on the lower edge tells us that the material is bronze, which is also indicated by the arrangement of lines in the cross-sectioning of the view.

A worm wheel is a toothed gear with the gear teeth cut at an angle with the sides of its rim. This angle is such as will make its teeth readily mesh, or fit, into the screw threads of the worm which is used to drive it. While the driving worm is not shown on this blueprint, a dimension line at the right of the view, with one of its arrow points touching the center line of the worm wheel and the other touching another center line drawn near the lower edge of the blueprint, shows that the center-to-center distance of the worm and the worm wheel is $3\frac{3}{4}$ inches. Lettered data near the lower center lines states that the worm wheel is to have thirty-two teeth of $\frac{1}{2}$-inch circular pitch and that the worm will have a left-hand thread, two threads to the inch.

In reading Plate III, let us first study the view itself. We will see that it is the view seen by a viewer facing the central axis of the piece and is, therefore, a front view. Lines drawn on the view at an angle with the working lines show that it is a sectional view, the piece having been cut along the center of its length precisely as a watermelon is sliced along the center of its length. Since the view is shown in this way, it is somewhat easier to read. The fact that one view only is given to work from indicates: (a) that if the work were viewed from its ends, the views would show on the blueprint as circles; and (b) that the ends of the work are plain and squared up—hub and rim. The lettered data, as already noted, states that the piece is a toothed gear wheel. Altogether, the piece is shown to consist of a hub, a rim, and a connecting web.

Following the upward extension lines and the dimension lines which they carry, it is seen that the over-all length of the piece is $2\frac{3}{8}$ inches and that the rim width is $1\frac{5}{8}$ inches. The upward extension lines and their dimension lines also show that the worm wheel hub extends, or projects, to the left of the rim a distance of $\frac{3}{4}$ inch. Dimension lines on the body of the view show: (a) that the wheel hub is $1\frac{15}{16}$ inches long; (b) that the rim overhangs the right end of the hub $\frac{7}{16}$ inch; (c) that the right end of the hub projects $\frac{1}{8}$ inch beyond the web; and (d) that the web is $\frac{1}{2}$ inch thick. Following the extension lines to the left of the view,

we learn that the hub is 3 inches in diameter and that the chucked hole in the hub must ream $1\frac{5}{8}$ inches. These extension lines also show that the over-all diameter of the toothed rim is $5\frac{1}{2}$ inches.

The curved diameter on the rim, as shown, is known as the throat diameter, to distinguish it from the over-all diameter. Following the extension lines to the left of the view, it is seen that the throat diameter is 5.4114 inches. The dimension line placed just over the rim with its arrow point touching the throat curve is drawn from the point where the short center line crosses the center line of the wheel rim. This dimension line indicates that the workman should machine the curved part, or throat, of the rim with a cutting tool having its cutting end formed to an arc of a circle of 1.0443 inches radius. The remaining radius dimension line has its arrow point resting on the curved working line which represents the inner surface of the wheel rim.

The teeth in worm wheel rims are invariably cut or machined by the use of a special tool known in shops as a *hob,* or a *hobbing cutter.* In using a hob to cut the gear teeth, the workman has to know to what depth the cutting teeth are to be sunk into the rim of the wheel. The sketch in the upper right-hand corner of Plate III indicates in outline the teeth, or threads, on the worm and on the hobbing cutter. This sketch shows: (a) the angle of the sides of the threads; (b) the center-to-center distance, $\frac{1}{2}$ inch; (c) the total depth of the hob thread, 0.3433 inch; and (d) the narrowest width of the hob thread and the space, 0.155 inch. The short note at the right of the view tells us that a keyway is to be cut in the surface of the hub hole $\frac{3}{8}$ inch wide and $\frac{3}{16}$ inch deep.

The *f* marks placed on the working lines of the view show that the sides and the outer surface of the rim and both ends and the hole through the hub are to be finished.

PLATE IV

INTERMEDIATE SHAFT CLUTCH

The piece shown in Plate IV is very nearly the same as that shown in Plate III. The practice is, however, that of another firm and the piece is represented by three views: a front view, a right end view, and a left end view. Reading the lettered data shows the piece to be an intermediate shaft clutch. The cross-section front

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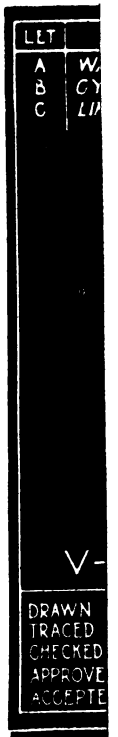
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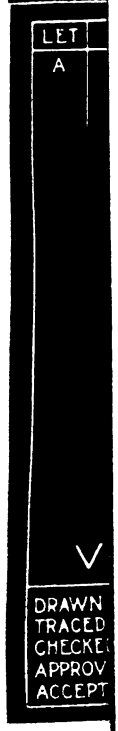
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view shows that the material is steel, and a further reading of the lettered note tells us that the company knows this steel as Carpenter No. 5–317 steel. The left end view shows the *general* form of the clutch teeth. A line drawn across this view near a single tooth shows that a section has been sliced off at this point. The line is lettered *A–B* at its opposite ends to enable the workman to find the view of the part sliced off.

Directly above the left end view is a small view named "section *A–B*". This shows a single clutch tooth viewed as if looked at from the inner, or small, end of the tooth. Extension lines projecting upward from the working lines of the tooth show that the tooth sides incline 5 degrees from the vertical. No other view shown tells us this, and therefore it is necessary for the workman to have this small section.

The right end view shows that the clutch teeth are slanted along their sides at an angle of 20 degrees, or, expressed another way, the sides of the clutch teeth make an angle of 20 degrees with each other. From a further study of this view, we learn that the inner surfaces of two adjacent teeth make an angle of 52 degrees. The lettered note at the right and the arrowhead tell us that the inner ends of the clutch teeth are counterbored $\frac{29}{32}$ inch in diameter and $\frac{1}{8}$ inch deep. Just above the front view at each end arrow points have the numerals 0.124–0.126. The decimal fraction for $\frac{1}{8}$ inch is 0.125; the numerals 0.124–0.126 then show that the $\frac{1}{8}$-inch depth must be cut to a tolerance of not more than 0.001 inch above or below the figured depth, $\frac{1}{8}$ inch. The right end view clearly shows that this shaft clutch has gear teeth in its outer surface, and data under the front view states that there are to be fifteen teeth, ten pitch. The only other note for the workman's use is that giving the size of the keyway.

PLATE V

DETAILS OF FOUR MACHINE PIECES

General Data. In the study of Plate V and of all succeeding plates, it will be assumed that the workman has thoroughly studied all that has gone before and understands what is meant by front, top, bottom, and end views, by sections, and by extension and dimension lines, and that he can find and read the dimensions.

Plate V is made up of four blueprints of small details and illustrates the way in which the Taft-Pierce Company send such into their shops. The number placed in the circle located in the upper right-hand corner of each small print is the part number of the piece and will be referred to in this text as the blueprint number. It will be noted that blueprints Nos. 63, 440, and 113 are all blueprints of bolts.

Swivel Table Stud. The piece shown in blueprint No. 63 is a swivel table stud for a semiuniversal grinding machine. A note placed just beneath the view states that the material is cold rolled steel, cyanide hardened. Only one view, a front view, is given, which indicates that the end views would show as circles. From this single view the workman can get all length dimensions and all diameter dimensions. Among the things to be noted in this blueprint are that the right end of the stud is to be threaded ten threads per inch and that some of the dimensions are given in pairs, for example, those of the body of the stud. This means that the length of the body and the diameter of the body, respectively, must lie within the given pair of figures for that dimension. Take the case of the body diameter; it must not be greater than 0.999 inch nor smaller than 0.998 inch, a tolerance of one-half of one-thousandth inch above or below a central dimension.

Wheel Guard T Bolt. Blueprint No. 440 is a wheel guard T bolt, and the note tells us that two are required and that the material is cold rolled steel. A front and a right end view are given. If a single front view of this piece were shown, the workman would infer that the bolt head was a circle; the end view shows that the bolt head is square. A left end view instead of a right end view would indicate this equally well, but in that case the circles which represent the body of the bolt would be dotted circles instead of showing as they do in the right end view. There are no finish *f* marks in either view because the piece, as noted, is made from cold rolled steel bar stock, which has a finished surface, and when the bolt is turned to size, the outer surfaces of the head have the original finish of the bar. Moreover, to construct the rest of the bolt naturally finishes those parts.

Diamond Tool Post T Bolt. Blueprint No. 113 is a diamond tool post T bolt, and the lettered note states that one is required

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and that the material is cold rolled steel, cyanide treated. Two views of this piece are necessary. The views differ from those shown in blueprint No. 440, since the view showing the bolt head is a left end view. Placed in this way, the circles which represent the body part of the bolt show as dotted circles. Another interesting thing is that the body dimension of the bolt is given by the dimension figures as $\frac{5}{8}$ inch, while a lettered note with an arrowhead tells us that the body of the bolt is turned to a diameter of $\frac{39}{64}$ inch and that the threaded part is $\frac{5}{8}$ inch in diameter and has eleven threads per inch. The end view shows that the bolt head inclines at an angle of 60 degrees with the base line.

Cross-Feed Connecting Link. Blueprint No. 345 shows a front view and a top view of a cross-feed connecting link. One only is required and both the lettered note and the arrangement of cross-section lines inform us that the material is cast iron. Where the shape of the cross-section is simple, as shown, it is usual to place it directly on one of the views rather than make an additional view. The cross-sections of pulley arms, connecting rods, and links are generally shown by this method. The workman in reading this blueprint should note that the reamed holes have limiting dimensions given and also that the thickness of the hubs is held to a small tolerance. The finish *f* marks clearly show what surfaces are to be machined.

PLATE VI

CENTER REST TOP

The lettered data states that Plate VI is a blueprint of a center rest top. One is required and the material is cast iron. A short study will show the machinist that many of the dimensions are given to or from horizontal or vertical center lines; also that some of the dimensions are plain distances, in which case the dimension line has an arrow point at each end, while others are from a center point and give the radius from that point of the working line which represents the surface. When a radius dimension is given, it is usual to place the initial letter *R.* or the letters *Rad.* after the dimension figures.

In the front view, the workman should especially note that the hole through the length of the upper part of the piece is to

be drilled and reamed a part of the way and drilled and tapped eighteen threads per inch for the rest of its length. Another important item is that, while the radius of the hub is given as $\frac{9}{16}$ inch, the frame back of the hub is machined back to a radius of $\frac{5}{8}$ inch.

In the right end view, the things which the machinist should especially note are that one end of the lower hub is marked *f*, while the opposite end is marked "disc grind", indicating that the *f* end is to be carefully finished to an accurate bearing, while it is not necessary to be so particular with the opposite end. The end view also shows that the hole in the hub is to be drilled and reamed. The hole just above the hub is to be drilled and tapped for a $\frac{5}{16}$-inch screw, eighteen threads per inch.

PLATE VII

CENTER REST BASE

A reader of this text who is familiar with machine work knows that a center rest is a fixture used in turning or grinding to give support and steadiness to long or slender work. Plate VIII gives a complete view of a center rest and indicates its use and, before taking up a study of Plate VII, it will be well to glance at Plate VIII.

The lettered title of Plate VII states that it is the blueprint of the center rest base. One is required and it is made of cast iron. The piece of work shown is then the mate of that shown in Plate VI and some of its features and dimensions are the same. A complete front view and a complete right end view are given as well as a portion of a top view, which is placed directly above the left upper corner of the front view.

The working lines of the bottom of the front view and the end view show that the base is provided with a squared projection used to locate the center rest on the bed of the machine. Aside from this, the machinist should notice the data which relates to finishing the small hub at the top of the end view and at the upper right corner of the front view. The term "spot face $\frac{7}{8}$"" indicates that the surface touched by the arrow point is to be finished, by using a counterbore $\frac{7}{8}$ inch in diameter, to the limiting thickness given just above the end view. It should be noted that

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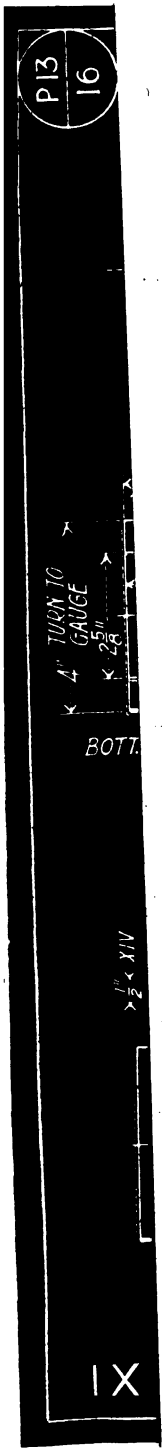

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certain of the holes are drilled and reamed while others are drilled and threaded with a tap. The machinist should carefully observe on which of the working lines of the views the *f* mark is placed. He should also note in Plate VII, as in Plate VI, that many of the dimensions are given to or from horizontal or vertical center lines and that all dimensions bear a certain relation to a common center, or axis, *A*. In reading the dimension figures, the machinist will find that several of them have a limiting error tolerance telling him that he must be especially accurate in those dimensions.

PLATE VIII

CENTER REST ASSEMBLY

Plate VIII shows two views, and the lettered title placed just below the views states that the piece is a center rest assembly. The two views furnish a line picture of the completed center rest and show all its separate parts as they are when *assembled* or, as it is often termed, *set up*. It will be noted that each and every part is given a number. These numbers are known as the piece, or part, numbers.

PLATE IX

WORK SPINDLE SLIDE

Compared with many of the blueprints shown, Plate IX, showing the work spindle slide, is difficult to read and it has been selected to illustrate a fairly complicated and irregularly shaped piece. As an aid in reading this blueprint, a short study should be made of the general form and shape of the piece as shown in outline in the front, right end, and top views. An examination of the views shows that the piece consists in general of two hubs, or cylinders, with holes through their length. The cylinders are placed with the smaller above the larger and are connected by a short web running their entire length. When the reader clearly sees this and has the picture clearly in his mind, he can then study the various small hubs, bosses, and other pieces attached to the two long hubs and their connecting flange.

In tracing the location and shape of the several parts, holes, etc., it should be kept clearly in mind that each part in the front view, if shown in the top or in the end view, will be squarely above or squarely to the right of its position in the front view.

Another thing which aids the reader in getting a picture of the piece in mind is its name, "work spindle slide." The note just over the name plate, "Scale Half Size," of course applies to the original blueprint only and not to the reproduction in this text.

Several helps in the form of lettered notes are on this blueprint. As an example, attention is called to a note at one end of the front view which tells us that the dotted lines on which the arrow points touch represent oil grooves $\frac{1}{4}$ inch wide and $\frac{3}{32}$ inch deep. From a study of the upper part of the front view and of the end view we learn at which points the oil grooves start and also that they are drilled at an angle of 45 degrees to reach the surfaces of the slide bearings.

Among the specially important things to be noted is that, while the hole through the length of the smaller of the two long hubs is a straight plain cylindrical hole, the hole through the larger is tapered at its right-hand end $\frac{3}{4}$ inch to the foot for a distance of $5\frac{1}{2}$ inches. Attention is also called to the two slide bearings on the rear side of the work, one slide bearing having right-angle sides and the other a 60-degree side. Threads per inch on blueprints at the shops of the Brown & Sharpe Manufacturing Company are invariably given by Roman numerals. For example, as may be noted on the blueprint, a hole threaded fourteen threads per inch is marked *XIV*. Also, each surface which is to be finished is indicated by drawing a brilliant red line close beside the working line which represents the surface. On this plate and on Plates XII and XIII these lines are shown dotted and are drawn close to the finished surface lines. Lettered notes placed on this blueprint state what special tools should be got from the tool room before starting the work.

PLATE X

DRAWING-IN BOLT

Plate X shows a drawing-in bolt, and the lettered note just below the name tells us that one is required, that the material is cold rolled steel, that it is a forging, that it is forged on a heading machine, and that it is to be casehardened as shown. The fact that the forging is done on a heading machine indicates that the head end only is upset to its rough shape. The letters *C.H.*

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placed just below the threaded end and just below the $\frac{3}{4}$-inch hexagon end show that the bolt is to be casehardened at these places, according to the lettered notes. One view only is given, which indicates that an end view would show circles unless otherwise specified. A note at the extreme left end of the view states that the end is made a $\frac{3}{4}$-inch hexagon.

All length dimensions are easily read with one exception, that of the over-all length, which is represented by the capital letter *A*. Notes lettered on the blueprint at the lower right-hand corner inform us that, when this bolt is made for and used on C2, *A* is $25\frac{7}{8}$ inches in length, and when it is made for and used on C3, *A* is $29\frac{15}{16}$ inches. While all the diameter dimensions are easily read, the machinist should surely note that several of them have lettered notes giving additional information. For example, we read that the $\frac{13}{16}$-inch diameter is to be ground 0.001 or 0.002 inch small, "Gr. $\left\{\begin{matrix}.001\\.002\end{matrix}\right\}$S." In this blueprint, the letters *Rad.* are used instead of the capital letter *R.* to denote a radius.

PLATE XI

KNEE SHAFT CLUTCH

The title plate at the lower right of Plate XI tells us that the piece of work shown is a knee shaft clutch. Further information given on the title plate indicates that this clutch is used on A3, AA3, BBH2, etc. A lettered note placed on the blueprint just below the two views states that the knee shaft clutch is to be made of machinery steel, that the rough stock is a piece measuring $2\frac{1}{16}''\times 2\frac{9}{16}''$, and that a certain formed tool is used by the machinist. All the length and all the diameter dimensions are easily found and read, while a copious use of notes gives the machinist much special information. For example, a lettered note placed just below the front view tells us that a certain hole is drilled in position after the piece is taken from stock. This indicates that when finished by the machinist to be placed in stock, this hole is left off and that when the setting-up man gets the piece from the stockroom, he places it in position and then drills it in place. Before starting work on this piece, the machinist should read all notes. The front view is a complete section.

In this blueprint, the information concerning the clutch teeth is contained in a small view placed somewhat above the front view and named a "development of clutch teeth." This view represents the outer surface of the clutch teeth rolled out on a flat surface, as explained in "Mechanical Drawing," Part III, page 107. The note tells us that the spaces between the teeth are 0.005 inch wider than the teeth. The view also shows that the sides of the teeth slant to an angle of 5 degrees. The end view is sufficiently complete to show the form of the clutch teeth only, a lettered note placed just below the view giving the number of clutch teeth as eleven. As both views show that the piece of work is by construction finished all over inside and out, no finish needs to be indicated.

PLATE XII

BACK TOOL POST

The title plate informs us that the piece shown in Plate XII is the back tool post and that there are a set of tool posts. A lettered note placed at the upper right tells us that the tool post material is M.I. and that it is to be casehardened to have a mottled surface. This plate, like Plate IX, lists up the special tool-room tools for the job. The views given are front, top, and end views supplemented by a small section view, placed just above the right end view, showing a section on line *A–B*.

This small *A–B* section shows that the bottom of the large slot running through the tool post is at an angle of 5 degrees with the back surface of the slot. The working lines of this slot, as shown in the front and the end views, indicate that the top surface of the slot is parallel to the top surface of the tool post and that the lower, or bottom, surface of the slot makes an angle of 20 degrees with a center line drawn parallel to the upper surface of the slot. Working lines, drawn as full lines in the front and the end views but dotted in the top view, show a projecting feather on the under side of the tool post base. Clearly defined dimension lines and figures give the width, depth, and length of the piece. The machinist should note that the width is to be made standard 0.001 inch small; also that certain base surfaces are to be surface ground.

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PLATE XIII

CENTER ARM HEAD

Plate XIII is in some respects similar to Plate IX. In reading this plate, the machinist should first strive to get a general picture of the piece well fixed in his mind. As an aid to this, he will first note that the work, a center arm head, consists of two principal hubs separated by a web or shank to give a center-to-center distance of $7\frac{1}{4}$ inches. The upper hub is simple, having as it does a plain hole through its length and a binder boss on its upper side to be drilled, tapped, and counterbored for a binder bolt. The lower hub, however, is well surrounded by projecting parts which, as they carry several holes and other finished surfaces, decidedly present difficulties to the reader. He will do well to take up each hole as shown in the end view and study each as a single hole, getting its position located in each view.

The larger hole, it will be noted, passes entirely through the main lower hub. The hole placed slightly above this hole and to the right hand of the end view can, by studying the front view, be seen to pass entirely through its hub from end to end. The upper hole of the three shown to the left of the main lower hole will be found to be placed on a center line with the one just noted. A small cross-section view just above, lettered "section *A–B*," aids the reader in clearing up the details of this hole and the two similar lower holes; he should carefully note where the section line *A–B* is drawn on the end view. A study of the front view and of the section view shows that the upper of the three holes passes entirely through the casting from end to end. A study of the two lower holes in the end view shows that they break into each other. Their location in the front view and in the small section view indicates that, while the hole farthest to the left passes entirely through the casting, the other, which cuts into it, is only $1\frac{1}{4}$ inches deep. Extensions of the centers of these two holes show by dimension figures that their center-to-center distance is $\frac{2\,3}{3\,2}$ inch, and a radius line just below the end view shows that the center of the outer hole is $2\frac{7}{8}$-inch radius from the center of the hole in the main lower hub.

Diagonally drawn dotted lines in the end view represent a hole coming in from the front of the casting at an angle of 22

degrees 35 minutes. In the front view this hole and its boss show at the side as a series of full and dotted circles. A lettered note placed on the end view at the right of the vertical center line of the view states that an oil hole is to be drilled. Following carefully the lines which represent the oil hole, the reader will find that it is to be drilled at an angle of 17½ degrees with the center line of a similar $\frac{3}{16}$-inch hole showing through the lower side of the main hub hole. Further examination of the end view draws attention to two small circles at the sides of one of the $\frac{7}{8}$-inch holes. A study of the small section view shows these circles to represent holes drilled, tapped, and counterbored for screws *H* having a $\frac{3}{8}$-inch filister head. A radius arc drawn from the hole beside which these screw holes are placed shows that their centers are placed at $\frac{9}{16}$-inch radius. Other screw holes, oil holes, and pin holes can easily be located by a study of the views. In reading a blueprint such as this, especial care must be used in locating all center lines, radius lines, extension lines, dimension lines, and lines showing angles.

PLATE XIV

BRASS GLOBE VALVE

Plate XIV shows a 1½-inch brass globe valve and the original blueprint is made to full-size scale. Two views only are given. The front view shows the valve sectioned as if cut down through and on the center line, thus clearly giving an inside view of the valve. The end view gives an outline of the valve and is in a sense a picture of the valve. The arrangement of the cross-section lines in the front view indicates that the sectioned metal parts of the valve are, with the exception of the cast-iron handwheel, brass throughout. By means of the outline view and the section, the draftsman has not only shown all the necessary dimensions of the valve as an assembly but has also shown those of each detail so well that the machinist can work it out. While it is not general practice in shops to have the workman work from assembly blueprints, it may well be done when a shop is building a standard article. As there are no finish lines nor *f* marks, the workman would have to decide for himself what surfaces should be finished, if given this drawing to work from.

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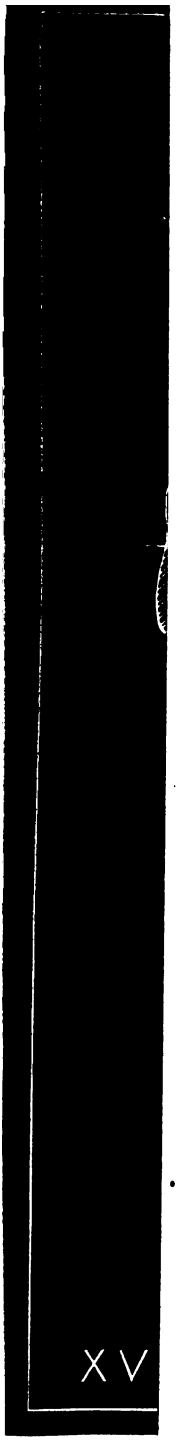
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the valve body, consisting of a globular shaped casting with threaded hexagon ends into which, on its upper side, is screwed the valve cover casting with a threaded bearing for the long spindle; and an upper part, consisting of a stuffing box for the wick packing. At the extreme upper end of the stuffing box are a small circular gland and a gland nut to force it along the valve spindle to compress the wick packing into the stuffing chamber. The valve spindle has on its top end a squared taper end to fit the cast-iron handwheel and a threaded hexagon nut to hold the handwheel in place. Toward its lower end an enlarged part of the valve spindle is threaded with a rather coarse-pitch Acme thread to fit the threaded bearing in the valve cap. The extreme lower end of the valve spindle is enlarged and finished to carry the valve disc which seats itself on the valve body seat to close the flow through the valve body from end to end. The disc, or upper, seat moves up and down in narrow guides, as shown in the front section view, and a lettered note placed just below this view states that these guides are to be bored $2\frac{3}{32}$ inches in diameter. The disc has in its lower, or seat, side a circular recess, $1\frac{15}{16}$ inches outside diameter by $1\frac{3}{16}$ inches inside diameter, for a fiber, leather, asbestos, or other seat ring. Two dotted lines about $\frac{3}{16}$ inch apart drawn diagonally across the inside of the valve body, as shown in the front view, represent a diaphragm rib. This is an interesting blueprint to read, as it is necessary to locate carefully all the *extension* lines to learn which *working* lines they extend. Care must also be taken to determine which lines many of the arrow points exactly touch.

PLATE XV

ASSEMBLED CONE GEARS

Plate XV illustrates a method of using an assembly drawing for shop purposes. The view shows a cone of four gears in section on a shaft. The arrangement of the cross-section lines indicates that the gears are made of machinery steel. As shown, the whole cone of gears is mounted on a steel sleeve which, in turn, runs on a composition sleeve. The whole combination is held in position on the shaft by steel collars having hexagon-head set screws. As is customary in such section views, the shaft is not shown sectioned.

Its ends, however, are shown as if broken off and the arrangement of the section lines at the break indicates that the shaft is of steel.

Immediately below each gear, as shown in the view, are placed the letters *A–B–C–D*. The first column of a lettered table placed in the upper right-hand corner shows that similar cones of gears are used on machines, size 2, 3, 4, and 5. The next column gives the number of teeth and the pitch of the teeth required in the gears *A–B–C–D* for the various sizes of machines. The remaining columns of the table give the outside diameter of each gear and its width of face. From this single section view, supplemented by the lettered table, the machinist should be able to get all the essential information for making these gears, with the exception of the hole diameter, which is not given. The two smaller cone gears are shown as if made from a plain steel blank, while the two larger gears plainly show that they have a distinct hub and rim with a thin web connection.

PLATE XVI

FACE GEAR

The two views of a special face gear shown in Plate XVI are half size in the original blueprint. The term "face gear" indicates that the piece represented is the large driving gear on the main spindle of the machine. While no finish *f* marks are found on the working lines of this blueprint, the average machinist would know that the outer diameter, the ends of the hubs, the holes through the gear, and the sides of the rim should be carefully and well finished. In addition to this, a lettered note at the upper right of the front view states that the surfaces indicated by the arrow points are rough turned. The title plate informs us that one is required and that the material is cast iron, which is also indicated by the arrangement of the cross-section lines in the front view.

The view looking toward the end of the gear hub shows that the upper small hub has a short supporting flange and that on its lower edge the upper hub is counterweighted. A lettered note placed just at the left of the front view tells us that the hole in the hub is keyseated $\frac{3}{32}$ inch deep and $\frac{5}{8}$ inch wide and that the key is dovetailed and drives into place. Both views show the key

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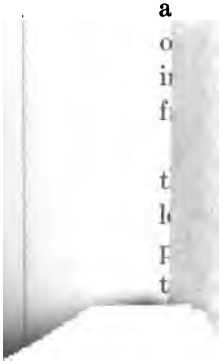

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in place. Another important lettered note states that there are eighty-seven teeth milled into the outer face of the piece and that they are to be six pitch. The workman should especially note that the over-all diameter is to be held to definite limits of tolerance.

PLATE XVII

DOWN-FEED WORM

The upper title plate states that the piece shown in Plate XVII is a down-feed worm for a 5-foot boring mill. One is required and the lower title plate gives the material as machinery steel cut from $3\frac{3}{4}$-inch rod $13\frac{1}{8}$ inches long, rough dimensions. Two views are given, with the front view sectioned to indicate steel. All dimensions are given on the front view. The end view is sufficient to show that in general the piece has circular outlines. The end view also shows the shape of the two keyways and, while no direct dimensions are given, this view shows the general position of the holes mentioned in the lettered note, "$\frac{1}{4}$" drill–$\frac{1}{4}$" deep–2 holes–drill in position".

In considering this piece of work, the machinist is, of course, first concerned with the reamed $1\frac{1}{2}$-inch hole through its length. After this hole is finished ready for the mandrel, he should carefully read all the notes and other lettered directions before beginning to square up and turn the piece. He should especially observe what surfaces are to be ground and give careful attention to the finished dimensions. He will note that certain dimensions have a small limiting tolerance given in thousandths of an inch. He should also note that, while the fine-pitch thread shown on the right end of the front view is a *right-handed* thread cut to suit a certain nut, the coarse-pitch 29-degree worm thread is to be cut *left-handed.* All dimension lines, figures, and extension lines are very clear and are easily located in reference to their working lines. The lettered notes have clearly defined arrow points to indicate the surfaces to which they refer. Attention is called to the diameter dimension reading "$2\frac{19}{64}$ inches neck". This shows that the piece is to be necked in to this diameter previous to grinding the $2\frac{5}{16}$-inch diameter as a protection to the corner of the grinding wheel. No finish *f* marks are shown, as the piece is finished all over, and this fact has been indicated by the initial letters

F.A.O. placed just below the front view. The $\frac{5}{16}$-inch hole showing just to the left of the flange collar should be drilled before cutting the keyway to give a clearance for the cutting point of the keyseating tool.

PLATE XVIII

SADDLE ADJUSTING LEVER

Plate XVIII, an assembly blueprint, is for the use of the setting-up machinist and clearly indicates how the group of parts which make up the saddle adjusting lever are assembled. It will be noted that each pin, cap screw, set screw, spring, lever arm, sleeve, etc., is given a part number and that an arrow point clearly indicates the part referred to. The arrangement of the cross-sectioning lines in the top view clearly indicates the material of each part; for example, they show that the lever arm *#14249* and its hub are cast iron, while the handle screwed into its upper end is of steel. While the shape and position of each part of this mechanism are clearly shown in this blueprint, no dimensions are given, which shows us that, as previously stated, the print is to be used in the shop only by the assembler. The reader in studying this blueprint should consider that he is to assemble the various parts and endeavor to decide in what order they should be assembled: for example, it is clear that *#20197*, *02268*, and *20180* must be placed in position in *#14249* previous to screwing *#20196* into it; also that *#14249* must be placed in position on *#14248* previous to attaching cover plate *#14246*.

PLATE XIX

TOP PULLEY BRACKET

The top title plate informs us that the several views shown in Plate XIX are of a top pulley bracket for a 5-foot boring mill and that two are required. The lower title plate states that the material is cast iron. The views are a front view, a right side view, and a top view, which is in this case projected and positioned just above the right side view. The arrangement of full and dotted lines indicates that the piece consists of a hollow base, or pedestal, having at its upper end a shaft-carrying box, or bearing, which, in turn, has a large grease, or oil, pocket on its upper side.

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In reading this blueprint, the machinist should observe that many of the dimensions given are for the use of the pattern maker and are of no especial concern to him. The pattern maker, on the other hand, is concerned with all the dimensions as he must add sufficient stock to every surface marked with an *f* to allow excess metal for the machinist's purposes. As an instance of this, take some of the dimensions as given on the front view and the right side view. We observe that at the extreme right hand of the side view a dimension of 14 inches is given from the lower line, or base, of the pedestal bracket to the center line of the box. While this is a dimension for the machinist in particular, the pattern maker must also note that the base surface is to be finished and make the dimension enough longer than 14 inches so that the machinist will have metal stock sufficient to allow him to finish the base surface and still have the correct dimension. Also, in considering the shaft hole given as $3\frac{1}{8}$ inches ream, the pattern maker must make his core prints and core boxes enough less than $3\frac{1}{8}$ inches in diameter to allow stock for machining the hole to the specified size. The pattern maker only is concerned with the dimension $\frac{1}{2}$ inch given for the wall thickness of the hollow pedestal and that of $9\frac{1}{4}$ inches given at the bottom of the side view for the width of the pedestal. These and many other dimensions are not subjected to any machining. The pattern maker, then, in reading this blueprint will carefully consider each and every working line, whether drawn full to represent a visible outside surface or drawn dotted to represent an invisible inside surface, in order to give himself a clear mental picture of the construction not only of the outer outlines of the piece but also of all the interior outlines. When the pattern maker has this clear mental picture of the piece, he can then readily trace the dimensions of all parts of his construction by following the extension lines.

If the pattern maker has fully understood the views up to this point he clearly sees: (a) that they represent a ring oiling pedestal bracket with the base cored out to leave walls $\frac{1}{2}$ inch thick, the cored portion to extend up from the base line of the bracket to within $\frac{1}{2}$ inch of the bottom surface of the cored oil chamber; (b) that the cored oil chamber is $4\frac{1}{4}$ inches in length in a direction across the shaft bearing and $1\frac{1}{2}$ inches in width along the shaft

hole, and that the oil chamber extends out toward the front of the bracket into a rounded-end projection, or lug; (c) that he must provide a loose pad on the front of the pedestal, as shown, "for belt drive only"; and (d) that the bottom surface of the bracket, the entire hole through the bracket box, the upper surfaces of the oil pocket, and the front face of the bracket pad are to be machined as indicated by finish *f* marks, and that excess stock for machining off must be allowed on such surfaces.

The machinist in reading the views should carefully note which surfaces are marked with the finish mark for machining. Starting at the pedestal base, as shown in the front and the side views, he will observe that its lower surface is to be machined and that certain holes are to pass through it. A study of the top view and its lettered notes shows that there are to be three holes through the base in each of its ends. Two of each three are drilled for holding-down bolts and one for No. 8 locating taper pins. The holding-down bolt holes are to be spot faced for the heads of the bolts.

Returning to a study of the front and side views, the machinist notes that the front surface of the pad is to be machined. This surface, as shown in the side view, is $4\frac{3}{8}$ inches from the vertical center line. Four $\frac{5}{8}$-inch tapped holes are to be drilled into the face of the pad $3\frac{3}{4}$ inches apart along the horizontal distance and $2\frac{1}{2}$ inches apart in the vertical dimension. Before machining the shaft bearing shown at the upper part of the front and the side views, the machinist should note: (a) that the bearing proper extends in length from the inner edge of a narrow circular oil-collecting pocket to the inner edge of a similar opposite circular oil-collecting pocket and that this bearing surface is bored and reamed to a diameter of $3\frac{1}{8}$ inches; (b) that outside of the circular oil-collecting pockets, the hole diameter is increased to $3\frac{5}{32}$ inches; (c) that while the circular oil-collecting pockets are marked *f* and are therefore to be machined, no dimensions are given, this indicating that they are simply machined to remove the original scale and to make them truly circular; and (d) that a large central oil-containing chamber is provided for an oil-conveying ring and that two oil-return holes are drilled from the edges of the two circular oil-collecting pockets at an angle which allows them to enter the

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central oil-containing chamber, the lettered note stating that these oil holes are $\frac{1}{4}$ inch in diameter. Two threaded holes are shown through the upper shell of the shaft-bearing box and a note attached by a line and an arrow point to the upper view explains that they are to be drilled $\frac{13}{32}$ inch for a $\frac{1}{2}$-inch tap. Finally, the upper surfaces of the oil box are marked *f* to be machined.

PLATE XX

SHAFT-BEARING PEDESTAL

Plate XX shows a shaft-bearing pedestal in which the shaft-bearing box is a separate unit (not shown) which may be supported inside the pedestal. As the shaft-bearing box would be held exactly central with the frame of the pedestal, many of the working lines of the left side view are drawn around the center line, or axis, and several of the dimensions are figured as a radius from a common center. The views consist of a front, or edge, view, a left side view, and two smaller views, one of which is a section on line *A–B* and the other is placed just below the side view and shows a bottom view of the feet of the pedestal.

Very little machine work is to be done on this piece, merely machining the base supports on their under surface, drilling holes in the feet for four holding-down bolts, and drilling, tapping, and spot facing the three prominent bosses. It will be noted by the machinist that the latter holes are at an angle of 120 degrees with one another. The machinist should also observe that the base supports are to be finished to give their under surface a distance of $9\frac{1}{2}$ inches from the center line, or axis, of the views. Practically all the remaining dimensions are given for the pattern maker's use and are easily located and read.

PLATE XXI

END SHIELD

In reading the front view, the small view, and the right end view of Plate XXI, the reader should clearly see that when he looks at the right end view, he is in fact viewing this *end shield* at its large open end. A study of the front section view shows that the casting essentially consists of a large cup-shaped portion at the right with only a rim bottom. A half rim is attached and

projects to the left and carries a circular hub having a circular hole of two diameters. In this blueprint the machinist, to understand the views, must carefully follow each working line of the drawing, locate each extension line, and note each arrow-pointed line.

All the important finished dimensions are given a limiting tolerance in thousandths of an inch. The rim edge of the large cup shown at the right of the front section view is finished to a 5.250-inch diameter and 0.094-inch depth; and three holes through the rim bottom are also finished. Two of these holes, $4\frac{15}{16}$ inches center to center, are counterbored for fillister-head cap screws, while the third hole, showing at the top of both views $2\frac{1}{4}$ inches up from the center line, is countersunk for riveting. A detail of this is given on the lower side of the blueprint. The circular hub which shows at the left of the front section view is machined on its outer end and a double-diameter hole is finished through it. Four holes are drilled and tapped into the outer face of the hub. A lettered note placed slightly to the left and above the hub gives the necessary information for these holes.

PLATE XXII

ARMATURE HEAD

Plate XXII is a combined assembly and detail blueprint and according to the title plate is made up of ① armature head assembly, ② armature head, and ③ stud (fan-supporting), the whole being given the title plate name armature head. The numbers 1, 2, and 3 are clearly shown in the blueprint placed near or on the views. The material of the stud is given in the title plate as cold rolled steel and that of the armature head as soft steel casting. The front view is shown in section on line *A–B–C*. The careful reader will note that section line *A–B–C* follows the vertical center line of the right side view from *A* at its lower edge to *B* at the center axis and then slants to the right and upward, following the center line of one of the three ribs to *C*.

Stud. A study of the front and the end views shows that the studs ③ (also shown at the upper right of the blueprint) are screwed into the three ribs just mentioned, and a lettered note placed on the sectioned front view states that they are machined to a bevel after assembling.

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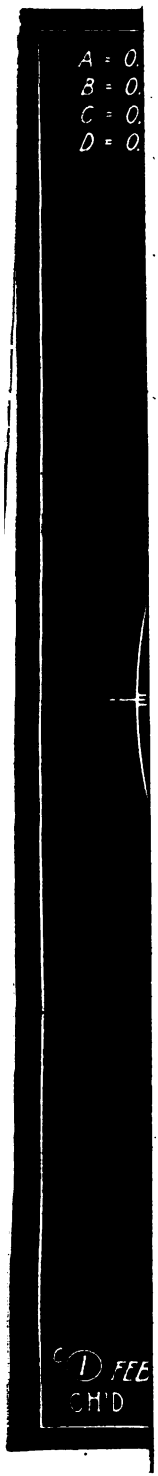
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A small detail section *A–A* placed just over the center of the side view shows the form of the slot on the section line *A–A* drawn across the upper edge of the side view. These slots, twelve in number, are shown by dotted working lines in the side view and are spaced evenly completely around the armature head at its extreme left end as the piece is shown in the front view.

Careful study of the views shows that the armature head casting is a circular cup having three narrow shallow ribs cast onto the inner side of its rim. It is into the outer ends of these ribs that the cold rolled steel studs are screwed, as shown. At the opposite, or base, end of the casting is located the outer flange for the slots shown in the detail section *A–A*. Extension lines drawn from the working lines of the flange carry a dimension line and arrow points which show that the flange diameter is $4\frac{3}{4}$ inches. The body rim of the casting is to be finished to an outside diameter of $4\frac{1}{8}$ inches. The hole through the hub of the casting, it should be noted, is finished to a diameter of 1.375 inches, with a tolerance of but one-half of one-thousandth inch above size and no tolerance below the figured diameter. The keyway is figured in the side view as being $\frac{1}{4}$ inch wide and $\frac{9}{64}$ inch deep. It must be noted that the keyway is located in the hub hole on the center line of a rib and not in the thinner part of the hub. The reader should observe that the radius of the rim side of the $4\frac{3}{4}$-inch flange is curved to a $\frac{5}{8}$-inch radius as shown at the upper left of the front view and that a corresponding radius of $\frac{1}{2}$ inch for the flange slots is shown at the lower left of the front view. The centers for these radius lines are shown as 2 inches from the center line of the piece and $\frac{1}{4}$ inch from the edge of the piece. A lettered note placed just below the side view gives the tapped stud holes as 14-24 tap–3 holes. The hole in the outer end of the stud is given as 10-32 tap–$\frac{5}{8}$ inch deep.

PLATE XXIII, Nos. 1 AND 2

DETAILS OF TYPICAL ARMATURE PUNCHINGS

General Data. Plate XXIII is made up of two D-size prints, each giving the details of a separate piece. For convenience in referring to them they have been given the numbers 1 and 2. Two other illustrations of a like construction are shown in Plate

XXIV. The pieces represented are punchings from sheet steel or sheet copper. The reader will note that a single complete view of each piece is shown supplemented by section details. The complete views, with the exception of blueprint No. 2 on Plate XXIV, are drawn to one-half scale in the original blueprint and the detail section views, in the original, are made to an enlarged scale about double size. These enlarged details show the form, size, and kind of holes to be made near the outer edge of the punching, as shown at the right of the complete views. A lettered note resting on an arrow states that there are to be eighty-three holes equally spaced around the punching.

Armature End Ring. The title plate gives blueprint No. 1 as an armature end ring punched from hard sheet copper 0.125 inch thick. The holes and the entire punching are made by using what is known as a perforating and shearing punch and die. The metal punched out of the hole, in this case, is turned, or bent, inward as shown in the enlarged details. A note with two arrow pointers tells us that this punching has two $\frac{1}{16}$-inch saw cuts.

Armature Punching. Blueprint No. 2 is an armature punching punched from standard quality soft sheet steel 0.014 inch thick. A single view shows the complete punching. It has a 7-inch hole of a maximum tolerance of 0.001 inch above size and the outside diameter is 10.960 inches with a minimum tolerance of 0.006 inch. The punching is provided with a keyway $\frac{1}{2}$ inch wide and $\frac{17}{64}$ inch deep. The outer rim is provided with eighty-three slotted holes equally spaced around the circumference. An enlarged view of these slots is placed just to the right of the complete view. Lettered notes with arrowhead pointers give all the slot dimensions.

PLATE XXIV, Nos. 1 AND 2

DETAILS OF TYPICAL FIELD PUNCHINGS

Field Punching. In Plate XXIV are shown two blueprints of which No. 1 is a field punching punched from soft sheet steel, standard quality, 0.014 inch thick. One complete view only is given but, as in the blueprints shown in Plate XXIII, there is an enlarged view of the slots. This enlarged view gives complete details of the slots and the exact dimensions with all limiting tolerances. A note placed below the complete view tells us that the

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slots are thirty-six in number. The punching has four lugs on its rim placed 90 degrees apart. The outer contour of each lug, the careful reader will observe, is made up of arcs of circles connected by short straight lines drawn tangent to the arcs. This gives an irregular outline to the lugs. The die maker will, of course, note that many of the dimensions for this punching are exact to quite small limiting tolerances.

Pole Piece Lamination. Blueprint No. 2 is a pole piece lamination, and the upper note informs us that it is punched from sheet steel, common quality, 0.0625 inch thick. When the reader considers the thickness dimensions of the punchings shown in Plates XXIII and XXIV, he will readily see why an edge view is not given except at an enlarged scale, as in the several detail views. Plate XXIV, No. 2, is drawn full scale in the original blueprint. Only two dimensions show limiting tolerances. Most of the radius lines are from a common center placed somewhat above the view and on its center line. Centers for the other radius lines are clearly defined by small circles inclosing the center points. Radius lines are clearly drawn and dimensioned with the arrow points touching the working lines of the view. The die maker should carefully locate that part of the working line to which each radius line refers.

PLATE XXV

GEARS USED ON 12-INCH MERCHANT MILL

The title plate tells us that Plate XXV shows gears used on a 12-inch merchant mill. The bill of material states that one of these is made from steel casting thoroughly annealed and the other from an open-hearth steel forging. In the original blueprint the views are drawn to a scale of 6 inches to 1 foot. Where two gears are shown and one is larger than the other, the smaller of the two is the pinion and the larger is the gear, and in reading this blueprint they will be referred to in this way.

The pinion is shown in two views, with the front view in section as if sliced through the center of its length. The end view at the left of the front view clearly shows the hole and its keyway through the pinion; other than this, it consists of three concentric circles representing the outside diameter, the pitch diameter, and

the root diameter of the pinion teeth. A lettered note placed just beneath the views tells the machinist that the pinion is to be hobbed and has twenty-four teeth of the regular 14½-degree involute form, five diameter pitch. The term diameter pitch refers the pitch of the teeth to the pitch diameter of the gear. Finish *f* marks show that the pinion is to be finished all over.

The views of the gear are arranged similarly to those of the pinion. Finish *f* marks show that the ends of the hub, the sides of the rim, the outer diameter of the rim, and the hole through the center are to be machined and that the inside of the gear rim on both its ends is chamfered as shown. The machinist should carefully note that the hole through the hub is bored 3½ inches in diameter and that the gear is to be forced onto its shaft with a pressure of 18 tons. The machinist should also observe that there are forty-eight 14½-degree involute teeth in the gear and that they are to be cut on a gear-hobbing machine. The pattern maker should especially note that there are six holes cored through the web of the gear. All dimensions and extension lines are clearly and plainly defined and so placed as to be easily read.

PLATE XXVI

BEVEL GEARS FOR ROLLS ON SHEET BAR AND SLAB-MILL STEAM FLYING SHEAR TABLE

The title plate of Plate XXVI informs us that the views shown represent a pair of bevel gears used on a 21-inch sheet bar and slab mill steam flying shear table. The bill of material shows them to be open-hearth steel castings thoroughly annealed. The front view of the gears is sectioned by a plane along their axes and shows the gear and the pinion with their teeth engaging, or in *mesh* as it is called. A pair of bevel gears are usually shown thus, and the reader should make himself familiar with this fact and should study every detail. The end view of the pinion and the end view of the gear are just sufficiently complete to show the hubs and the holes and keyways through the hubs.

A lettered note *A* states the number of teeth in the pinion, the form of the teeth, the pitch of the teeth, and how they are to be machined. A lettered note *B* gives like information for the gear. When reading these lettered notes, the machinist should

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not fail to observe that the gear teeth are 20 degrees involute instead of the ordinary 14½ degrees, also that the pitch of the teeth is given as circular pitch instead of the more common diameter pitch. Circular pitch is the distance from the center line of a tooth to the center line of the next tooth and is measured along the pitch circle. In bevel gearing, it is measured at the largest pitch diameter.

The machinist, after carefully reading the lettered notes, is next concerned with the holes through the hubs of the gear and of the pinion. He will note that the gear is to be forced onto its shaft with a pressure of 15 tons and that in the pinion the hole should be a tight fit on the shaft. He will also observe that each keyway is to taper at the rate of ⅛ inch per foot. The machinist's next concern is the outside diameters of the gear and of the pinion. By following the extension lines to their dimension lines he learns that the gear is 14.725 inches and the pinion 9.705 inches outside diameter. He then locates the angles which give him the cone form of the pinion and the gear blank and notes that they are given in degrees and minutes. By using a bevel protractor in his measurements he can readily machine the cone sides and edges to the required angles as given on the blueprint. Making the length of the tooth an even 3 inches as given completes the pinion and the gear blanks (so far as the tooth rims are concerned) ready for cutting the teeth. The back end of each hub is faced up and its end circumference is machined into a circular groove of definite dimensions which are easily found and noted.

Previous to planing the teeth, the machinist should locate the angle marking the bottom of the tooth space. This angle is known as the *cutting angle,* and in this blueprint the reader will find it for both gear and pinion near where the center lines of the gear and the pinion cross each other. For the gear, the cutting angle is 54 degrees 37 minutes and for the pinion it is 29 degrees 19 minutes. The total depth measured at the outer end of the teeth should be noted. This is given as ⅜ inch+0.45 inch. As such gears as these are usually planed on a special gear-tooth planer, no further directions need to be given. The pattern maker will find in this blueprint all the necessary dimension lines, radius lines, and figured angles for a complete pattern for each gear.

PLATE XXVII

MOTOR COUPLING FOR ROD MILL DRIVE

Plate XXVII shows the parts of a motor coupling for a rod mill drive. The bill of material notes six parts *A–B–C–D–E–F* and gives the material from which each part is made and the number of each required. In the original blueprint all the views are one-quarter size, 3 inches to 1 foot. Lettered note *1* gives special shipping directions, and a most important note placed in the center of the end view gives explicit directions regarding the size of the hole and states that it is to be shrunk on the motor shaft. The front view of the coupling body *A* is sectioned through the center of its length. For the pattern maker, this is a simple job and he can make no mistakes in finding his dimension lines and figures.

The machinist who carefully reads the views will note that many of his dimensions are given to a special fixed gage. The note on the end view states that the hole is to be bored 0.007 inch small to allow a shrink fit. The keyway in the side of the hole is to be tapered $\frac{1}{8}$ inch per foot. A note at the hub end of the front view shows that this end of the hole is to be chamfered.

There are two hole keyways $\frac{15}{32}$ inch deep at the deeper end and a broad shallow keyway across the face of the flange part of the coupling, $1\frac{1}{8}$ inches deep and $3\frac{1}{2}$ inches wide to gage. Finish *f* marks on the working lines of both views indicate that the piece is machined all over. The smaller details of the coupling *B–C–F* are given near the right end of the blueprint. *F* shows two views of the key which fits the broad keyway machined across the face of the coupling flange; one end of the key is curved, as shown, to a radius of $10\frac{7}{8}$ inches. A $1\frac{9}{16}$-inch hole is shown drilled near the curved end and this helps us to understand that a flange bolt *B* passes through this end of the key when it is fitted in place in the face of the flange. The width dimension shows that it is to gage. The flange coupling bolts *B* with their nuts *C* are shown by a front and an end view. The front view shows the nut *C* in place, which is a common way of showing bolts and nuts. A hole is shown drilled through the body of the bolt near its threaded point for a $\frac{5}{16}$-inch cotter pin. The end view gives the shape of the bolt head and nut and shows it is chamfered at its outer corners.

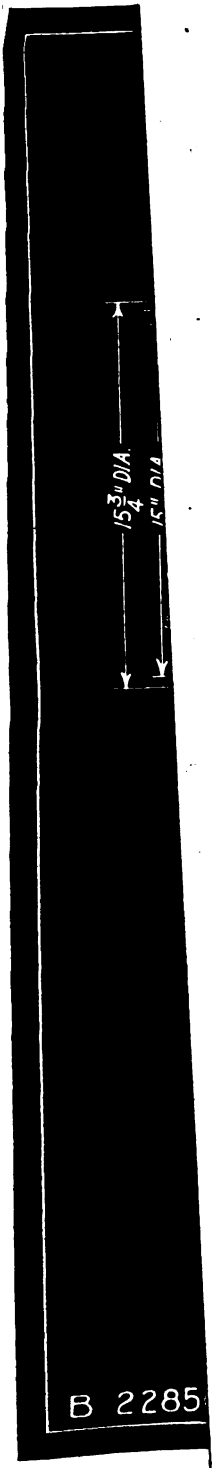
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PLATE XXVIII

BINDER ARM FOR ROPE TAKE-UP

The title plate shows that the views in Plate XXVIII are of a binder arm for rope take-up used on the cooling beds of a 21-inch sheet bar and slab mill. A long bill of materials is given. The title also tells us that in the original blueprint the views are drawn to a scale of 3 inches to 1 foot.

The views are complete and this is a very interesting blueprint for either a pattern maker or a machinist. For example, the reader will note that at the right-hand upper part of the front view the bearing cap is shown in place on its bearing by a series of dash and dot lines known as *broken lines*. This gives a sort of *skeleton* view of the cap. At the same place is a skeleton view of a bushing marked *A18059F*. Looking this number up in the bill of materials, the reader finds that the bushing is made of lumen bronze and that eight are required for four binder arms. Directly below this part of the view and at its extreme lower edge, similar skeleton views are shown of a cap *A18059C* and a bushing *A18059D*. In looking for these numbers in the bill of materials, the reader finds the names of the parts, the material used, and the number required for four binder arms. When the reader has carefully located each part in the bill of materials, he should consider its name, the number required, and the material used. The bill of materials shows that the binder arm is marked *A*, that it is made from a steel casting, and that four are required.

Another interesting matter relating to this blueprint is the method used in sectioning various parts of the views to open up the bearings clearly to the reader. A bottom view of the lower bearing is shown placed just below the side view and a similar top view of the upper bearing is placed just above the left side of the front view. The machinist must finish the four bearings to fit the caps and the lumen bronze bushings and drill a pin hole $3\frac{29}{64}$ inches in diameter for *A18070G* through the length of two circular hubs plainly showing in the lower half of the front and the side views. In addition, he must drill a $\frac{1}{2}$-inch oil hole in the upper part of the lower bearing and a hole just below each of the upper bearing and tap for a $\frac{1}{2}$-inch pipe plug. The machinist will also note that both ends of all four bearings and the inner ends of the pin

hubs are finished and that a spring brass wiper is riveted into each of the upper boxes near its inner end.

The pattern maker will note that the framework of the piece is a simple rib construction for supporting the several bearings and hubs and that the working lines are well dimensioned.

The upper bearings are complicated by having to be cored for an oil well, or chamber. The oil in this chamber is distributed to the shaft by means of a tinned steel universal chain *A18059Y* hung on the shaft into the enlarged part of the center of the oil chamber. The pattern maker should also note the special cored holes through the outer and the inner ribs showing just below the long pin hubs. Finish *f* marks placed across certain working lines of the view show the pattern maker for which surfaces he must allow an excess of metal for the machinist's needs. The bolt holes in the upper bearings for *A18059W* are cored, while those in the lower bearings for *A18059V* are drilled by the machinist.

PLATE XXIX

PARTS OF SHUTTLE MECHANISM FOR LOOM

Plates XXIX, XXX, and XXXI are each made up of four small blueprints originally $4\frac{1}{2}'' \times 5\frac{1}{2}''$ and show the practice of the Crompton-Knowles Loom Company. The small $4\frac{1}{2}'' \times 5\frac{1}{2}''$ blueprints are those used in their shops as working blueprints. Each small blueprint is from a *free-hand* sketch of some part of one of their machines and contains all that the workman needs to know when machining the piece. Blueprints made like those which we have been studying are used by the pattern maker.

A number placed in a circle has been added to each small blueprint to make it easy to refer to and each is provided with a title plate which contains certain information useful to the workman. For example, the title plate of the small blueprint No. 1 tells us that the piece is a rocker iron for a shuttle change motion on a medium duck loom and that the material is cast iron. Blueprint No. 2 shows the lower part of a shuttle carrier; No. 3, a stand for a lifter; and No. 4, the top part of a shuttle carrier. In many of these blueprints no over-all dimensions are given, and as they are not made to any particular scale of sizes, in such cases the sketch artist places the over-all length of the piece in the upper

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left-hand corner in small numerals over or on a short line; for example, the piece in blueprint No. 1 is 21 inches long. While this dimension is of no value to the machinist, it does aid the stores keeper in handling the castings, for, while each sketch is a picture of the piece in so far as its outlines are concerned, unless the small numerals are read, there is nothing in the view to indicate whether the piece is inches or feet in length. While such working blueprints are not commonly used, it is worth the reader's while to study them, as they show very clearly the use of free-hand sketches.

It must be borne in mind that in certain lines of machine building, while a given machine may consist of a great many parts, each part may be a very simple piece requiring but little or no machining; for example, blueprint No. 1 shows a piece of work that is to have four drilled holes, two of which are tapped; No. 2 shows a piece with one drilled hole; No. 3 is marked "no labor" and shows a piece of work in which the holes are made in the foundry by the use of properly shaped cores; and No. 4 is a little more complicated, having two $\frac{5}{16}$-inch tapped holes $3\frac{1}{4}$ inches apart and one $\frac{1}{4}$-inch tapped hole with the end of the hole boss, faced.

PLATE XXX

DETAILS OF GEARED MECHANISM USED ON CROMPTON-KNOWLES LOOM

In Plate XXX, blueprint No. 1, which represents a stand for a gear guard, is shown in the same manner as the blueprints in Plate XXIX. When pieces are sketched in this way, they are said to be shown in *perspective;* they are also termed picture sketches, as they are shown tipped and swung around from the regular squarely viewed position of the ordinary blueprint. Blueprints Nos. 2, 3, and 4, Plate XXX, representing a spur gear on the crankshaft, a hub for a pulley, and a spur gear on the bottom shaft, respectively, are shown viewed squarely from the front, and the real difference between them and most of the blueprints which we have studied lies in their being made by free-hand pen methods rather than by the use of drawing instruments. An end view of blueprint No. 2, 3, or 4 would show a series of concentric circles. Finish *f* marks indicate the working surfaces which are to be finished by some method of machining.

In Nos. 2 and 4 two dotted working lines and a lettered note tell us that a $\frac{5}{16}$-inch keyway is to be machined in the surface of the holes through the central hubs of these gears. In the case of No. 2, a lettered note states that four $\frac{9}{16}$-inch holes on a $6\frac{7}{8}$-inch circle are to be drilled through the web of the gear, and the sketch shows that these are placed in slightly raised hubs, or bosses. It will be noted by the careful reader that, while in most instances the finish *f* marks are placed in the usual manner on the working lines of the views, in some cases they are given with the dimension figures. As a case in point, take the diameter of the longer hub in No. 2. Here the finish *f* mark follows the dimension figures thus, $2\frac{3}{4}''$ *f*. Several similar cases will be noted in these sketches by the interested reader. While most machine gears have "cut" teeth, this is not universally so on certain lines of machinery and lettered notes at the top of No. 2 and No. 4 state that these gears have "cut" teeth.

PLATE XXXI

MISCELLANEOUS MECHANISMS USED ON CROMPTON-KNOWLES LOOMS

Plate XXXI, like the two preceding plates, is made up of four blueprints originally $4\frac{1}{2}'' \times 5\frac{1}{2}''$. Reading the title plate, we learn what each piece is and the material used. Blueprints Nos. 1, 2, and 4 show, respectively, a stand for a shipper and lock lever, an angle iron post, and a guide for a lifter rod, and they are picture, or perspective, views. No. 3 is the ordinary type of free-hand sketch and shows a front and an end view of a ratchet and pinion. While no special directions are needed in reading, attention is called in No. 1 to the $\frac{5}{8}$-inch hole near the lower part of the piece. While this shows the stud *#4757* in place, the stud is evidently a separate piece. In No. 2, the long shank has no finish *f* marks but is marked $\frac{3}{4}''$ *f*. In No. 3 two views are necessary to show that one set of teeth is on a slender hub.

PLATE XXXII

BRASS CHECK VALVE

First-Angle Projection. While "Mechanical Drawing," Parts I, II, and III, does not analyze in detail the method of projection

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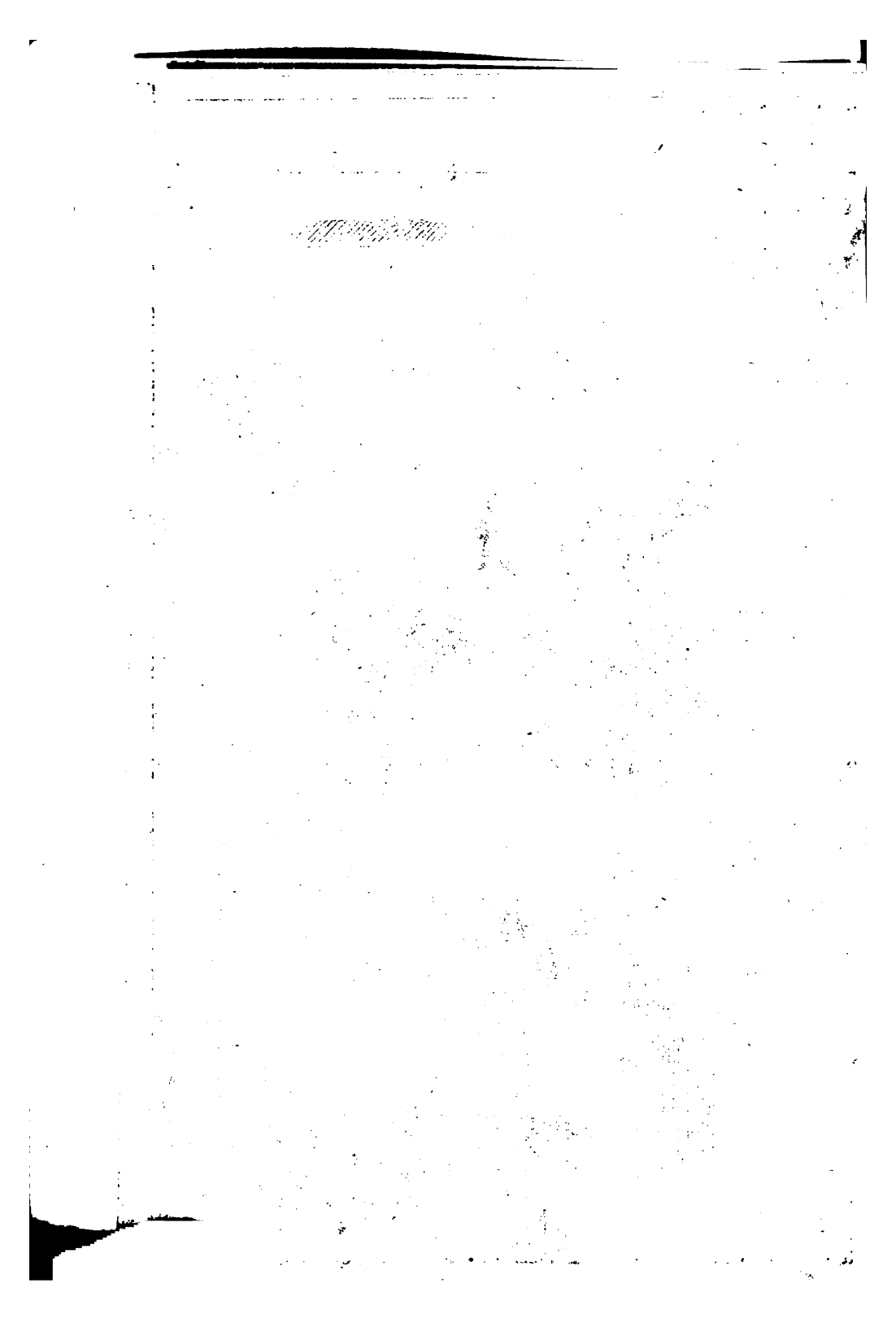

used in Plate XXXII, readers of blueprints often have such placed in their hands. The blueprints of machine parts shown in this text are, with this one exception, drawn in what is known as third-angle projection. In addition to what this book contains on views and their arrangement, "Mechanical Drawing," Part III, defines and illustrates first-angle and third-angle projection and the blueprint reader should study the opening pages of Part III. In Fig. 97, Part III, the reader will note that the lines of the piece viewed are sent forward on a plane surface. In other words, instead of placing the object we are viewing on the far side of some material like plain glass and viewing it through the glass and then making on the glass a sketch of what we see, the object is placed in front of the glass and we make the sketch on the glass as if we sighted along its edges and drew lines on the glass in line with the edges we were sighting. Looking at an object in this manner places the right end view in the blueprint at the left side of the front view instead of at the right side as in previous blueprints, and the surface lines seen in looking down on the top of the object are shown below the front view.

Placing of Views. If this method is clear in the reader's mind, let him return to Plate XXXII. He will observe that the front view of this $1\frac{1}{2}$-inch brass check valve has been placed at the upper left-hand corner of the sheet. Just below the front view and centered with it is the view one would get of this valve if he were viewing it on its top side, or upper surface. By the regular third-angle system of placing views, the top view would be shown above the front view. The end view, as the careful reader will note, represents the view one would get if looking at the left end of the front view. While it is, then, a view of the left end of the valve and would, in ordinary view arrangement, be placed at the left of the front view, it is by the first-angle arrangement of views placed at the right of the front view. In tracing the location of a line from one view to another, the blueprint reader will need to use care if he is not accustomed to this method of showing views.

Details of Blueprint. Other than the arrangement of views, this blueprint is easily read, having, as it does, a hollow spherical body with hexagon ends and a circular hole in its upper side, a hexagon cap screwed into the top side hole, and an internal

swing hinged valve flapper. A tapped hole in the upper right corner of the body is made at an angle of 40 degrees with the axis of the valve body and into this is screwed a special plug as shown. The flapper is hinged on a small diameter spindle which is centered and held in place by two bearing plugs placed opposite each other in the body of the valve. The flapper consists of a hinged frame, a circular disc having a ring of leather or asbestos in its under side groove, a bolt, a nut, and a washer to hold the ring in the disc groove and the ring and disc onto the hinged frame.

PLATE XXXIII

SPINDLE

When interpreting Plate XXXIII, the reader will note from the title plate that the spindle is made from 15-point machine steel. Fifteen point when used in this manner means that the carbon content in the steel is fifteen-hundredths of one per cent. The shop man and the mill man shorten this by saying or writing it 15 point. A front view only is needed to show all the necessary outlines of the spindle and to give all the necessary dimensions for the workman as an end view would consist of a series of concentric circles except for the keys and their seatings.

Dotted lines centered with the center line of the work and drawn from end to end of the view show a hole through the length of the spindle. A lettered note tells us that in the right-hand, or nose, end of the spindle this hole is No. 12 taper to a plug depth of 6 inches. In producing the hole, the workman would first drill a hole $7\frac{5}{8}$ inches deep plus or minus $\frac{1}{8}$ inch, using a $1\frac{3}{16}$-inch drill, and then he would continue the hole completely through the length of the spindle, using a 1-inch drill. A lettered note with an indicating arrowhead informs us that the rear end of the hole is to be chamfered $\frac{1}{8}$ inch for center. Another lettered note states that the spindle bearings are to be pack hardened at least $\frac{1}{16}$ inch deep. A lettered note placed near the nose of the spindle tells us that the $3\frac{1}{4}$-inch and the $3\frac{1}{2}$-inch diameters are to be a forced fit in part #4470. Some makers of working blueprints use the term press fit instead of force fit. Either term would indicate that part #4470 is to be pressed onto the spindle at the places indicated by the arrow points. The lettered

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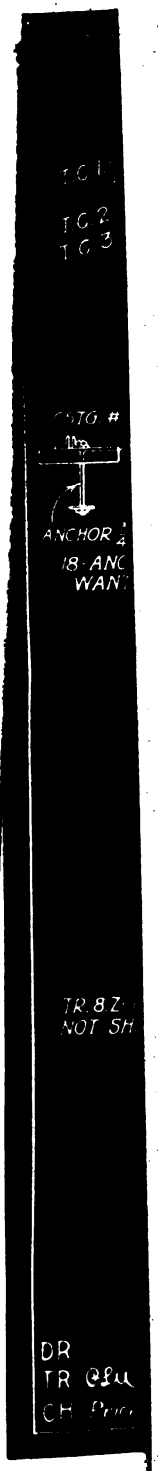
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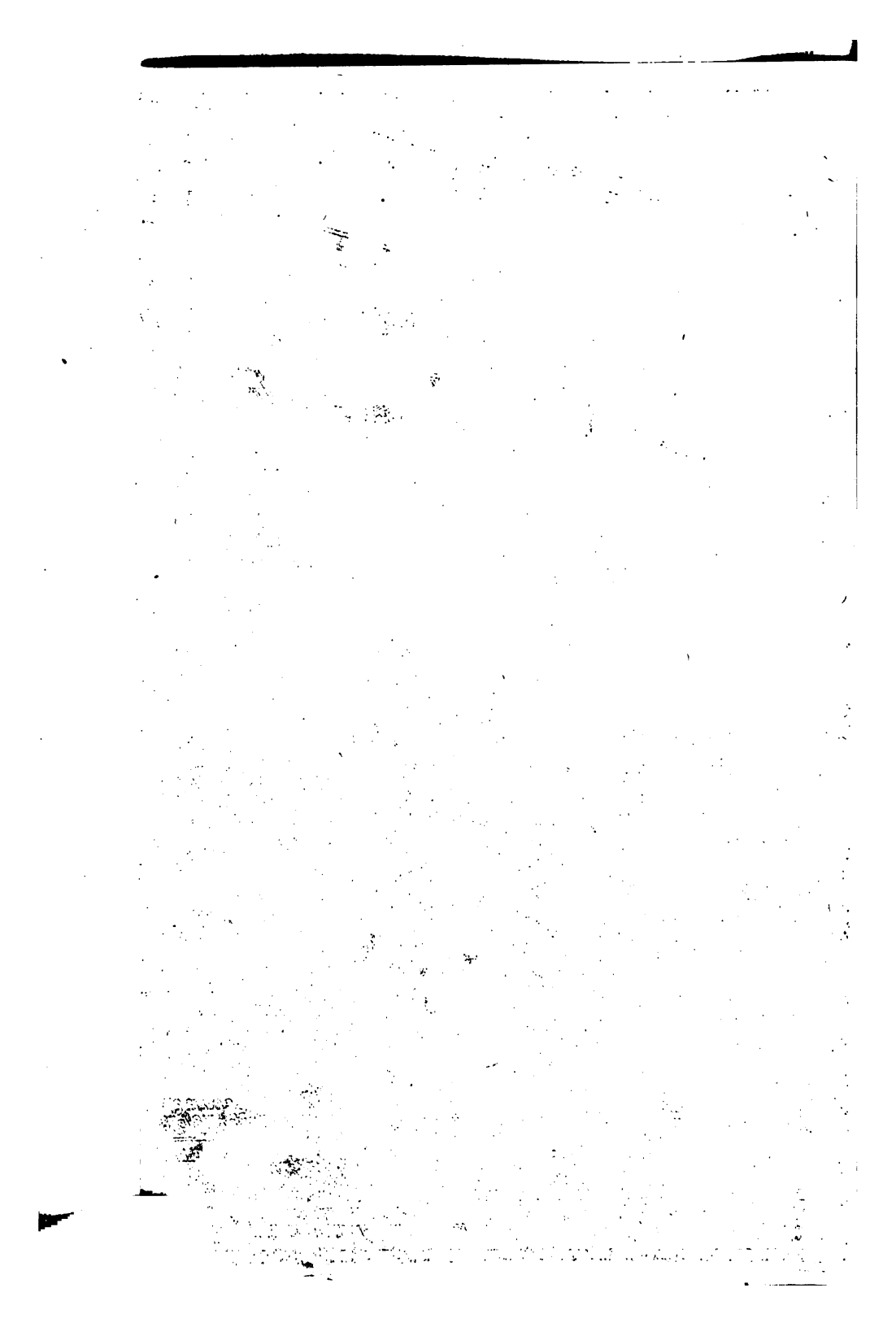

note placed at the left end of the spindle refers to a wringing fit. A wringing fit is one in which the parts are so fitted in dimensions as to have to be wrung, or twisted, together; some workmen interpret this to mean a fitting so snug that the pieces go together by lightly rapping them. In any case, it means a fit so snug that a little forcing is needed to slip the pieces together. The reader's attention is called to the limiting tolerances as expressed by the plus and minus signs and to the printed directions placed at the lower edge of the sheet which state that "unless otherwise specified, limits on this drawing are $\pm 0.005''$; dimensions of angles $\pm 1°$; and reamed or bored holes standard to 0.001" small". The term Woodruff key refers to the Whitney system of using Woodruff keys.

PLATE XXXIV

ROOF TRUSS

Plates XXXIV and XXXV are shown for the reason that the average shop man may be at times called upon to use such. Plate XXXIV shows a piece of structural work known as a roof truss. The word "truss" is shortened to *Tr.* on the blueprint. Steel structural work such as trusses, beams, girders, and columns is usually made up of angles, I beams, channels, plates, etc., riveted in such a manner as to get the desired construction. The various angles, channels, etc., are known as shapes and are hot rolled at the steel mills, straightened, and sold in open market.

The truss shown in Plate XXXIV is built up of angles of varying lengths riveted together and to flat pieces of plate known as gussets, or sometimes gusset plates. The several pieces of angles are given a letter symbol. In the roof truss shown the short pieces of angle steel used to tie the upper and lower parts together are symbolized by *D* and show on the blueprint as *D–1*, *D–2*, etc. The gusset plates are symbolized by *G* and appear on the blueprint as *G–1*, *G–2*, etc. In many cases a truss is too long to ship complete and has to be partly completed at the place used, or, as it is termed, in the field, and rivets driven after the truss leaves the shop are known as field rivets. The rivets which are to be driven while the truss is being built in the shop are indicated in the blueprint by small full circles, while the position of field rivets is shown on the angles by small white circular spots.

Noting what has been said relative to riveting, it will be observed that the blueprint shows that this truss is to be shipped in three sections and field riveted at the place where it is to be used.

A steel angle as rolled has the form shown in Fig. 2. The upright and the horizontal parts are known as the legs of the angle. In the truss shown, two of these angles about 30 feet 10 inches long are placed back to back to form the left half of the upper slant of the truss. In the same manner, two angles about 29 feet $11\frac{3}{16}$ inches long are placed back to back to form the right upper half of the truss. Previous to riveting the angles together for making each top slant, gusset plates as shown at *G–1*, *G–2*, *G–4*, *G–5*, and *G–7* are slipped between the angles and the whole is riveted together. In a like manner, the lower chord of the truss is riveted up. It will be noted that the gusset plates *G* are trimmed to come flush at the outer surfaces of the truss, but that they project into the inside of the truss a distance sufficient to allow the several short angles to be riveted to them. It will also be observed that when the angles are riveted together back to back with gusset plates, the surfaces of the legs of the angles are separated by an amount equal to the thickness of the gusset *G*. Any rivets driven through the angle plates at space points held apart by the gussets have small washers slipped into the crack, or space, between the angles, and the rivets are then set up through the washer. This is shown on the blueprint by means of a dotted circle around the space rivets. It must be noted that the bottom chord of the truss is not made up of single-length angles but is spliced at points about 15 feet $4\frac{1}{8}$ inches from each end of the truss. Where a splice such as this occurs in the bottom chord of a truss, it is strengthened by riveting a splice plate onto the bottom of the angles, covering and tying the splice.

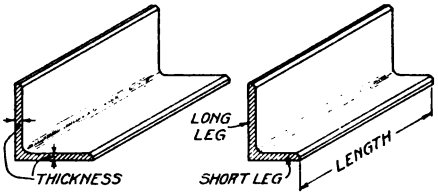

Fig. 2. Details of Angle Sections

Instead of giving in degrees and minutes the angle one piece makes with another, as is done in machine shop drawings, a small triangle is placed on the piece, as shown at the upper end of angle *D–3* and on its lower side. This means that the line

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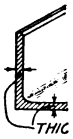

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on the gusset plate along which the rivet holes are to be placed rises from a base line $8\frac{11}{16}$ inches in 12 inches. The layout man accordingly measures off a base line on the gusset 12 inches in length and erects a perpendicular line on one end $8\frac{11}{16}$ inches in height. From this height he may scribe a line to the other end of the 12-inch base line and this is the gage line for the rivet holes. In all structural steel work the rivet holes are spaced along lines located a given distance from the back of the angle. These lines are termed *gage* lines and are not center lines in the usual sense. For example, in the view shown the reader will note that in the top member of the truss in the front view there are two gage lines and therefore two lines of rivets.

It will be observed that, while the top view of the truss is placed above the front view as in previous blueprints which we have studied, it parallels the slant of the truss. If a bottom view were given of this truss, it would show as if viewed from inside the truss; such a view is distinctly different from the bottom views already studied, and this point should be carefully noted in reading structural drawings.

PLATE XXXV

PLAN OF FOUNDRY BUILDING

Plate XXXV shows the plan of a foundry building. While the blueprint is more than ordinarily complete, it fairly represents such plans. The walls of the building are of brick and the windows are the prominent features of the walls. The reader should observe that the outside dimensions of the building, the door sizes, and the thickness of the walls are given; the columns, posts, interior walls, and partitions are located; the center-to-center distances are given; the foundry equipment is given and its position located on the plan; all stairways are indicated; and room measurements are given. Attention is called to the method of representing the windows by means of two parallel lines placed across the openings in the brick wall and to the method of showing the doors swung partly open. The plan shows a gallery floor along one side of the building. On this floor are located the office of the foreman, the charging floor for the cupolas, the motor room, etc.; the gallery floor is supported partly by the 9-inch latticed channel

columns and partly by a series of 6-inch round cast-iron columns. Three sets of doors are shown opening into the air and one opening into a tunnel to the shop. As a means of carrying off roof water and drainage from the pickling bed and cleaning room, a soil pipe line is shown. As most of this line of pipe is placed beneath the floor, it appears in the blueprint as a double dotted line. Two tile-lined chimneys are shown; one of these is for the brass furnace and one for the core oven. The core room is partly inclosed by means of a low wall capped with cast plates. The 8-foot door opens onto a driveway as do the two 5-foot 8-inch doors. These driveways and the street along the front of the building are not shown in the plan, but the street location could be assumed by the fact that the soil pipes, the clay drain, and the water pipes extend beyond the wall in a certain direction.

PLATE XXXVI

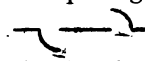
TYPICAL FIRE INSURANCE MAP

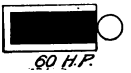
In fire insurance work the graphic description of a property has an important function; the custom is to show a plan or simple diagram of the insured properties, Plate XXXVI, adding certain simple devices for indicating such features of the building as may conveniently be described in this manner.

The map of a fire insurance risk gives the general location of the risk and its position relative to other risks. It also shows a scale drawing of the ground plan of the building, giving the dimensions, area, and, at the same time, a perfect idea of its general contour and the relation of the subdivisions of the building. By varying the thickness of the wall lines they are made to represent different kinds of walls. Unfinished or incomplete walls are represented by dotted lines; open spaces in the line indicate where the wall is interrupted or where a window opening occurs. Color is used to a large extent to indicate the different forms of construction; certain symbols, which follow in a measure the shapes of the things they represent, are used to shorten the description; and of course the use of initial letters is too well known to be more than mentioned. These symbols, it must be understood, are purely arbitrary but, having become established and recognized, they form the *symbol* language of the inspector and must be studied in a practical way in

WHOLE SALE
GROCERIES
WHOLE SALE

order to be recognized when presented. A few of these symbols and their description are given to convey some idea of the manner in which the map may be interpreted.

A solid thick line ——— represents an independent wall. A solid thin line represents a party wall. A distinct break in the line representing a division or side wall —— —— indicates an opening made by a doorway or arch. A small curved line  or a short line at right angles indicates the presence of a fire door, the auxiliary line being placed on the side of the wall the door is on. An auxiliary line on each side indicates a fire door on each side of the walls. A double curved line is used to represent a standard fire door. A little black dot on the inside end of a window line indicates a window opening on that side of two adjoining walls. If the black dot is missing, it means that there is no window on this floor. A single curve over the end of the window line represents a non-standard fire shutter. A straight line indicates the presence of wire glass. The initial H within a hollow square is used to represent a hoistway or hatch.

The letter S within a hollow square is used to represent a stairway. A stairway is also represented by a rectangular outline crossed by straight lines supposed to represent the stair steps. A solid black oblong figure represents a horizontal boiler, while a solid black circle represents a vertical boiler. A thin line around the solid black oblong figure 

and the margin colored in red represents a horizontal steam boiler which is bricked in. A small thin-lined circle with diagonals and a black dot at their intersection

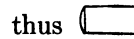
indicates an automatic sprinkler riser. A sprinkler pressure tank is represented thus  .

Plate XXXVI is a copy of a map issued in connection with the adoption of these symbols by the Fire Underwriters Uniformity Association and brings into use practically all the symbols needed.

MUSIC BUILDING FOR DOANE COLLEGE, CRETE, NEBRASKA
Dean and Dean, Architects, Chicago
For floor plans and longitudinal section, see opposite pages 109 and 141, respectively.

MECHANICAL DRAWING

PART I

The subject of mechanical drawing is of great interest and importance to all mechanics and engineers. Drawing is a method of showing graphically the minute details of machinery; it is the language by which the designer speaks to the workman; it is the most graphical way of placing ideas and calculation on record. A brief inspection of an accurate, well-executed working drawing gives a better idea of a machine than a lengthy written or verbal description. The better and more clearly a drawing is made, the more intelligently the workman can comprehend the ideas of the designer. Thorough training in this important subject is necessary to the success of everyone engaged in mechanical work.

The draftsman is dependent for his success, to a certain extent, upon the quality of the instruments and materials which he uses. As a beginner, he will find a cheap grade of instrument sufficient for his needs; but after he has become expert, it will be necessary for him to procure those of better construction and finish to enable him to do accurate work. It is a better plan to purchase the well-made instruments, if possible, at the start.

INSTRUMENTS AND MATERIALS

Drawing Paper. In selecting drawing paper, the first thing to be considered is the kind of paper most suitable for the proposed work. For shop drawings, a manila paper is frequently used on account of its toughness and strength, for these drawings are likely to be subjected to considerable hard usage. If a finished drawing is to be made, the best white drawing paper should be obtained, so that the drawing will not fade or become discolored with age. A good drawing paper should be strong; should have uniform thickness and surface; should stretch evenly and lie smoothly when stretched

or when ink or colors are used; should neither repel nor absorb liquids; and should allow considerable erasing without spoiling the surface It is, of course, impossible to find all of these qualities in any one paper, as great strength cannot be combined with fine surface. However, a kind should be chosen which combines the greatest number of these qualities for the given work. Of the higher grades of p[a]per Whatman's are considered by far the best. This paper, e[ach] of which may be used, is made in three grades: the *hot pressed,* which has a smooth surface and is especially adapted for pencil and very fine line drawing; the *cold pressed,* which is rougher than the hot pressed, has a finely grained surface, and is more suitable for water color drawing; and the *rough,* which is used for tinting. For general work, the cold pressed is the best as erasures do not show as plainly on it, but it does not take ink as well as the hot pressed.

Whatman's paper comes in sheets of standard sizes as follows:

Cap	13×17 inches	Imperial	22×30 inches
Demy	15×20 "	Atlas	26×34 "
Medium	17×11 "	Double Elephant	27×40 "
Royal	19×24 "	Antiquarian	31×53 "
Super-Royal	19×27 "		

The usual method of fastening paper to a drawing board is by means of thumb tacks or small one-ounce copper or iron tacks. First fasten the upper left-hand corner and then the lower right, pulling the paper taut. The other two corners are then fastened, and a sufficient number of tacks placed along the edges to make the paper lie smoothly. For very fine work, however, it is better to stretch the paper and glue it to the board. Turn up the edges of the paper all the way round—the margin being at least one inch—then moisten the surface of the paper by means of a sponge or soft cloth, and spread paste or glue on the turned-up edges. After removing all the surplus water on the paper, press the edges down on the board, commencing at one corner and stretching the paper *slightly*—if stretched too much it is liable to split in drying. Place the drawing board in a horizontal position until the paper is dry, when it will be found to be as smooth and tight as a drum head.

Drawing Board. The drawing board, Fig. 1, is usually made of well-seasoned and straight-grained soft pine, the grain running lengthwise of the board. Each end of the board is protected by a

side strip—$1\frac{3}{4}$ to 2 inches in width—whose edge is made perfectly straight for accuracy in using the T-square. Frequently the end

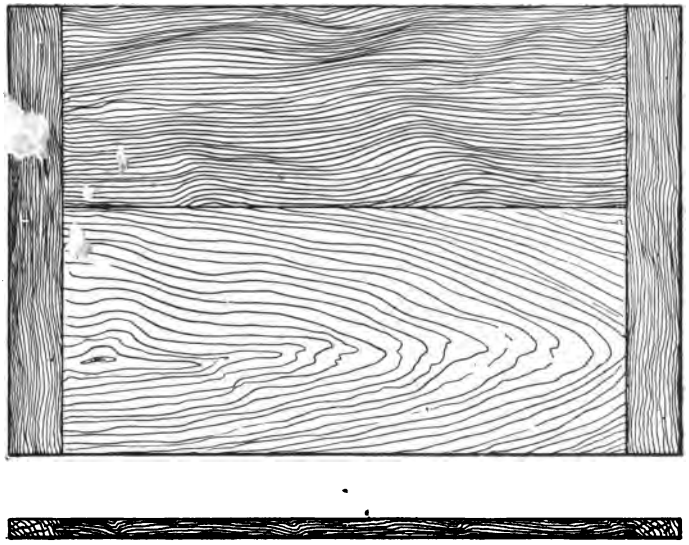


Fig. 1. Drawing Board

pieces are fastened by a glued matched joint, nails or screws. Two cleats on the bottom, extending the whole width of the board, will reduce the tendency to warp. Drawing boards are made in sizes to accommodate the sizes of paper in general use.

Thumb Tacks. Thumb tacks are used to fasten the paper to the drawing board. They are usually made of steel, pressed into shape—as in the cheaper grades—or with heads of German silver, the points being screwed and riveted to them. For most work, draftsmen use small one-ounce copper or iron tacks, as they are cheap and can be forced flush with the drawing-paper, thus offering no obstruction to the T-square.

Pencils. Lead pencils are graded according to their hardness, the degree of which is indicated by the letter H—as HH, 4H, 6H, etc. For general use a lead pencil of 5H or 6H should be used, although a softer 4H pencil is better for making letters, figures, and points. The hard lead pencil should be sharpened as shown in Fig. 2 so that in penciling a drawing the lines may be made very fine and light. The wood is cut away so that about $\frac{1}{4}$ or $\frac{1}{2}$ inch of lead

projects. The lead can then be sharpened to a chisel edge by rubbing it against a bit of sand paper or a fine file, and the corners slightly rounded. In drawing the lines the draftsman should place the chisel edge against the T-square or triangle, thus enabling him to draw a fine line exactly through a given point. If the drawing is not to be inked, but is made for tracing or for rough usage in the shop, a softer pencil, 3H or 4H, may be used, so as to make the lines somewhat thicker and heavier. The lead for compasses may also be sharpened to a point although some draftsmen prefer to use a chisel edge for the compasses as well as the pencil.

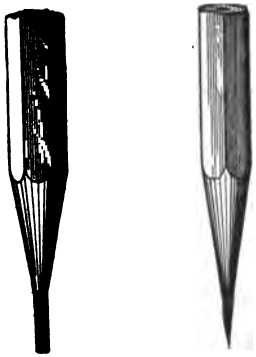


Fig. 2. Pencil Sharpened to a Chisel Point

In using a very hard lead pencil a light pressure should be used as otherwise the chisel edge will make a deep impression in the paper which cannot be erased.

Erasers. What little erasing is necessary in making drawings, should be done with a soft rubber. To avoid erasing the surrounding work some draftsmen use a card in which a slit is cut about 3 inches

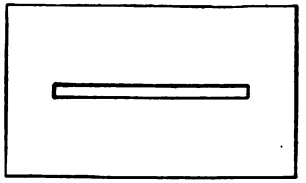


Fig. 3. Erasing Shield

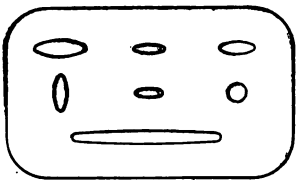


Fig. 4. Metal Erasing Shield

long and $\frac{1}{8}$ to $\frac{1}{4}$ inch wide, Fig. 3. An erasing shield of thin metal, Fig. 4, is also very convenient, especially in erasing letters. For cleaning drawings when they are completed, a sponge rubber or a preparation called "art gum" may be used, but in either case care should be taken not to make the lines dull by too hard rubbing.

T-Square. The T-square, which gets its name from its general shape, consists of a thin straight-edge, the *blade*, with a short piece, the *head*, fastened at right angles to it, Fig. 5. T-squares are usually made of wood, the pear and maple woods being used in the cheaper grades, and the harder woods, like mahogany, with protecting edges

of ebony or celluloid, Fig. 6, in the more expensive instruments. The head is designed to fit against the edge of the drawing board, allowing the blade to extend across the surface of the board. It is

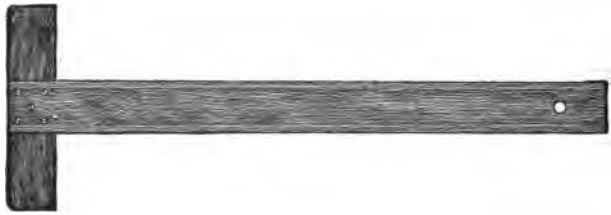


Fig. 5. Common T-Square

desirable to have the blade of the T-square make a right angle with the head, but this is not absolutely necessary, if the head is always placed against the left-hand edge of the board, for the lines drawn

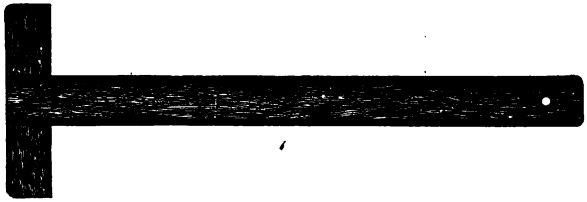


Fig. 6. Mahogany-Bound T-Square

with the T-square will then be referred to one edge of the board only, and if this edge is straight, the lines will be parallel to each other.

T-squares are sometimes provided with swiveled heads as it is frequently very convenient to draw lines parallel to each other which are not at right angles to the left-hand edge of the board. To use the T-square in drawing parallel horizontal lines,* place the head of the T-square in contact with the left-hand edge of the board, Fig. 7, and draw the pencil along the *upper edge* of the blade at each new position of the T-square. Only the upper edge should be used as the

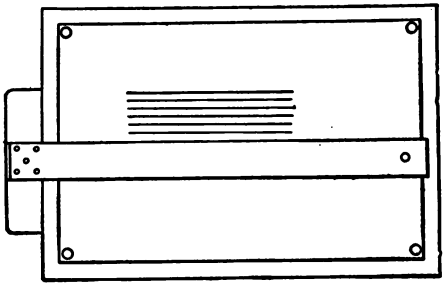


Fig. 7. Drawing Parallel Lines

* See page 23.

two edges may not be exactly parallel and straight. In trimming drawings or cutting the paper from the board, always use the *lower edge* of the T-square so that the upper edge may not be made untrue.

For accurate work it is absolutely necessary that the upper edge of the T-square be exactly straight. To test the straightness of the edge two T-squares may be placed together as shown in Fig. 8. However, a lack of contact such as shown in the figure does not prove which edge is crooked, and for this determination a third blade must be used and tried with the two given T-squares successively.

Fig. 8. Testing the Edge of T-Square

Triangles. Triangles are made of various substances such as wood, rubber, celluloid, and steel. Wooden triangles are cheap but are likely to warp out of shape; rubber triangles are frequently used, and are, in general, satisfactory; celluloid triangles are extensively used on account of their transparency, which enables the draftsmen to see the work already done even when covered with the triangle.

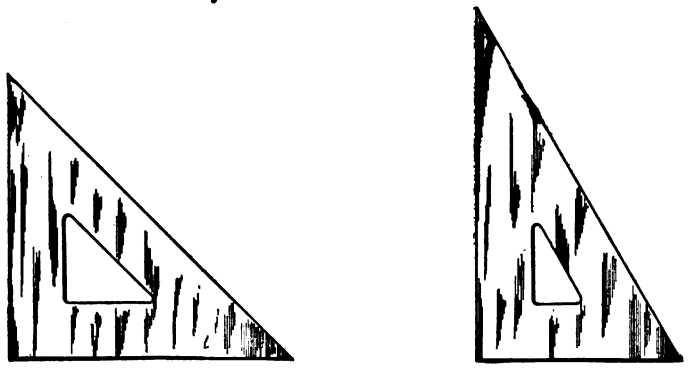


Fig. 9. 45° and 30° – 60° Triangles

In using a rubber or celluloid triangle take care that it lies perfectly flat and is hung up when not in use; when allowed to lie on the drawing board with a pencil or an eraser under one corner it will become warped in a short time, especially if the room is hot or the sun happens to strike the triangle.

Triangles from 6 to 8 inches on a side will be found convenient for most work, although there are many cases where a small triangle

measuring about 4 inches on a side will be found useful. Every draftsman should have at least two triangles, one having two angles of 45 degrees and one right angle; and the other having angles of 30, 60, and 90 degrees, respectively, Fig. 9.

The value of the triangle depends upon the accuracy of the angles and the straightness of the edges. To test the accuracy of

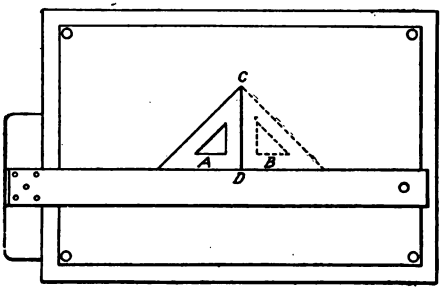


Fig. 10. Testing a Right Angle (45° Triangle)

the right angle of a triangle, place the triangle with the lower edge resting on the T-square in position *A*, Fig. 10. Now draw the line *C D*, which, if the triangle be true, will be perpendicular to the edge of the T-square. Transfer the triangle to position *B*, and if the right angle of the triangle is exactly 90 degrees the left-hand edge of the triangle will exactly coincide with the line *C D*.

To test the accuracy of the 45-degree angles place the triangle with the lower edge resting on the working edge of the T-square,

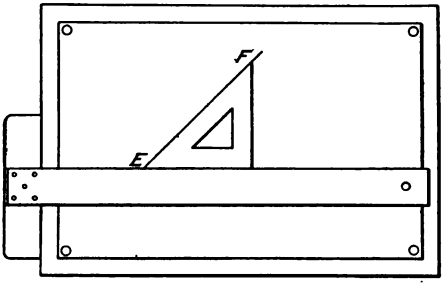


Fig. 11. Testing 45° Angle (45° Triangle)

and draw the line *E F*, Fig. 11. Now without moving the T-square place the triangle so that the other 45-degree angle is in the position occupied by the first. If the two 45-degree angles coincide they are accurate.

Triangles are used in drawing lines at right angles to the T-square, Fig. 12, and at an angle with the horizontal, Fig. 13. If it is desired to draw a line through the point *P*, Fig. 14, parallel to a given

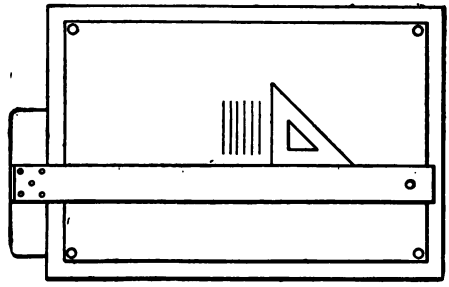


Fig. 12. Drawing Vertical Parallel Lines

line *E F*, two triangles should be used. First, place triangle *A* with one edge coinciding with the given line. Now take triangle *B* and place one of its edges in contact with the bottom edge of triangle *A*. Holding triangle *B* firmly with the left hand, slide triangle *A* to the right or to the left until its edge reaches the point *P*. The line *M N* may then be drawn passing through the point *P*. In place of the triangle *B* any straight-edge such as a T-square may be used.

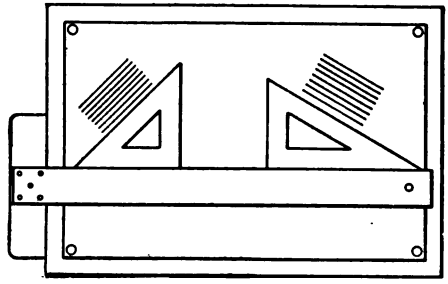


Fig. 13. Drawing Parallel Lines at an Angle with the Horizontal

A line may be drawn through a point, perpendicular to a given line by means of triangles as follows: Let *E F*, Fig. 15, be the given line, and let the point be *D*. Place the longest side of triangle *A* so that it coincides with the line *E F*. Place the other triangle (or any straight-edge) in the position of the triangle *B;* then holding *B* with the left hand, place the triangle *A* in the position *C*, so that the longest side passes through the point *D*. A line may then be drawn through the point *D* perpendicular to *E F*.

In previous figures it has been shown how lines may be drawn making angles of 30, 45, 60, and 90 degrees with the horizontal.

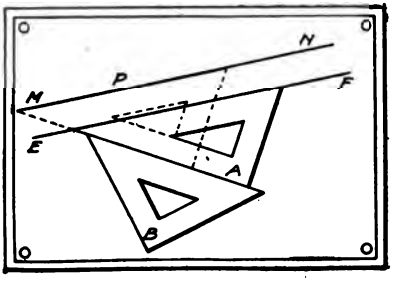


Fig. 14. Drawing a Line Parallel to a Given Line

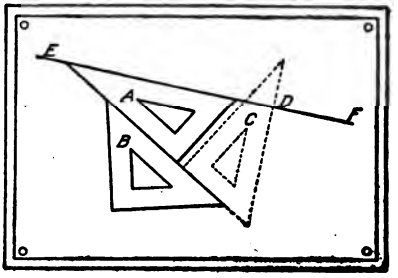


Fig. 15. Drawing a Line Perpendicular to a Given Line

It is possible to draw lines forming angles of 15 and 75 degrees by placing the triangles as shown in Fig. 16.

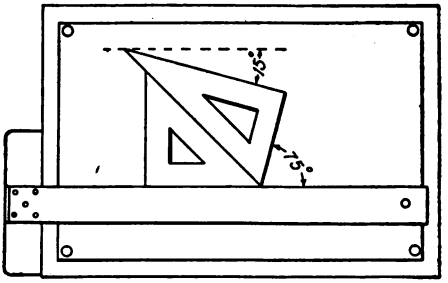


Fig. 16. Drawing Angle of 15° and 75°

By the use of the triangles and T-square almost any line may be drawn. Suppose it is desired to draw a rectangle having one side

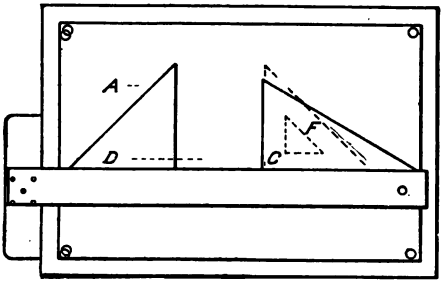


Fig. 17. Drawing a Rectangle with T-Square and Triangle

horizontal. First draw by means of the T-square the sides $A\,B$ and $D\,C$ horizontal and parallel, Fig. 17. Now place one of the

triangles on the T-square and in positions *E* and *F* draw the vertical lines *D A* and *B C*.

If the rectangle is to be drawn in some other position on the board, as shown in Fig. 18, place the 45-degree triangle *F* so that the longest edge is in the required direction of the side *D C*. Now, hold the triangle *F* in position and place another triangle in position *H*. By holding *H* in position and sliding triangle *F*, the sides *A B* and *D C* may be drawn. To draw the sides *A D* and *B C* change triangle *F* to position *E* and repeat the process.

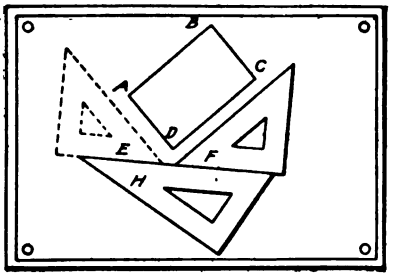


Fig. 18. Rectangle Drawn with Triangles

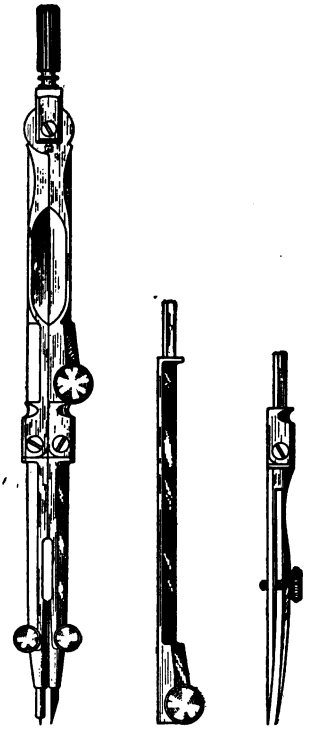


Fig. 19. Compasses and Attachments

Compasses. Compasses are used for drawing circles and arcs of circles. The cheaper class of instruments are made of brass, but they are unsatisfactory on account of the odor and the tendency to tarnish. The best material is German silver, as it does not soil the hands, has no odor, and is easy to keep clean. Aluminum instruments possess the advantage of lightness, but on account of the softness of the metal they do not wear well.

The compasses are made in the form shown in Fig. 19 and are provided with pencil and pen points. Fig. 20 shows the compass in position for drawing circles. One leg has a socket into which the shank of the pencil or pen mounting may be inserted. The other leg is fitted with a needle point which is placed at the center of the circle. In most instruments the needle point projects through a piece of round steel wire with a square shoulder at one or both ends.

In some instruments the joints are held in position by lock nuts,

made of thin disks of steel, with notches for using a wrench or forked key. Fig. 21 shows the detail of the joint of a high grade instrument. Both legs are alike at the joint, and two pivoted screws are inserted in the yoke. This permits ample movement of the legs, yet gives the proper stiffness. The flat surface of one leg is faced with steel, the other with German silver, so that the rubbing parts may be of different metals. Small set screws are used to prevent the pivoted screws from turning in the yoke. The contact surfaces of this joint are made circular to exclude dirt and to prevent rusting of the steel face.

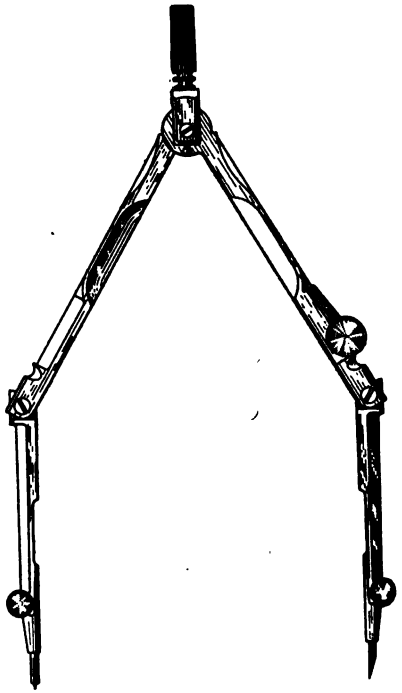


Fig. 20. Compasses Set for Drawing Circles

The details of the socket are shown in Fig. 22, Fig. 23, and Fig. 24; in some instruments the shank and socket are pentagonal, Fig. 22, the shank entering the socket loosely, and being held in place by means of the screw. Unless used very carefully this arrangement is not durable because the sharp corners soon wear, and the pressure on the set screw is not sufficient to hold the shank firmly in place.

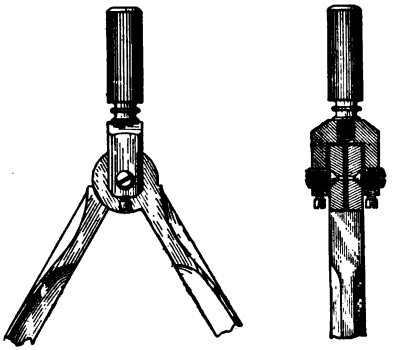


Fig. 21. Details of Compass Joint

In Fig. 23 is shown a round shank, the shank having a flat top, with a set screw to hold the shank in position. A still better form of socket is shown in Fig. 24, the hole being circular and tapered. The shank fits accurately into the split socket and is clamped by a screw on the side; it is held in perfect alignment by a small steel key.

Both legs of the compass are jointed in order that the lower part

of the legs may be perpendicular to the paper while drawing circles. In this way the needle point makes but a small hole in the paper, and both nibs of the pen will press equally on the paper. In penciling circles it is not as necessary that the pencil should be kept vertical;

Fig. 22. Pentagonal Shank and Socket

Fig. 23. Circular Shank and Socket

it is a good plan, however, to learn to use them in this way both in penciling and inking. The compasses should be held loosely between the thumb and forefinger. If the needle point is sharp, as it should be, only a slight pressure will be required to keep it in place. While drawing the circle, incline the compasses slightly in the direction of revolution and press lightly on the pencil or pen.

Fig. 24. Circular Socket with Set Screw

Fig. 25. Dividers

In removing the pencil or pen attachment from the compass it should be pulled out straight in order to avoid enlarging the socket, and thus rendering the instrument inaccurate. For drawing large circles use the lengthening bar, Fig. 19, steadying the needle point with one hand and describing the circle with the other.

Dividers. Dividers, which are similar to compasses, are used to lay off distances on the drawing, either from a scale or from other parts of the drawing, Fig. 25. They are also used for dividing a line into equal parts. To do this turn the dividers in the opposite direction each time, *i. e.*, move the point alternately to the right and to the left. The points of the dividers should be very sharp so that the holes made in the paper will be small, thus assuring accurate spacing. Compasses may be used as dividers by substituting for the pencil or pen point an extra steel point, usually furnished with the instrument. In place of dividers many draftsmen use a *needle point.* The needle, with the eye-end broken off, is forced into a handle of soft pine, making a convenient instrument for marking line intersections and distances.

Bow Pen and Bow Pencil. Ordinary large compasses are too heavy and the leverage of the long leg is too great to allow small circles to be drawn accurately. For this reason the bow compasses, Figs. 26 and 27, should be used on all arcs and circles having a radius of less than $\frac{3}{4}$ inch, such as those which represent boiler tubes and bolt

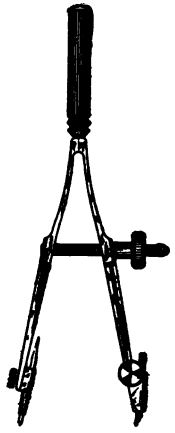


Fig. 26. Bow Pencil

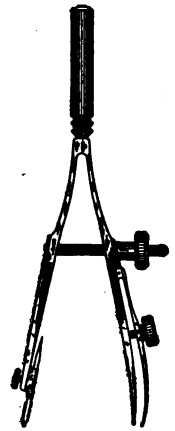


Fig. 27. Bow Pen

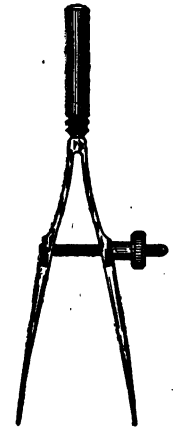


Fig. 28. Bow Divider

holes. When small circles are drawn, the needle point must be adjusted to the same length as the pen or pencil point. If a considerable change in radius is made, press the points together before turning the nut so as to prevent wear in the screw threads. The bow dividers, Fig. 28, replace the ordinary dividers in small work and have the advantage of a fixed adjustment.

Drawing Pen.* For drawing straight lines and curves that are not arcs of circles, the line pen—sometimes called the *ruling pen*—is

Fig. 29. Drawing Pen

used, Fig. 29. The distance between the pen points, which regulates the width of line to be drawn, is adjusted by the thumb screw, and the blades are given a slight curvature so that there will be a cavity for ink when the points are close together.

*See page 22.

The pen should not be dipped in the ink but should be filled by means of a common steel pen or quill, to a height of about $\frac{1}{4}$ or $\frac{3}{8}$ inch; if too much ink is placed in the pen it is likely to drop out and spoil the drawing. Upon finishing the work wipe the pen with chamois or a soft cloth, because most liquid inks corrode the steel.

In using the pen, care should be taken that both blades bear equally on the paper, in order that the line may be smooth. The pen is usually inclined slightly in the direction in which the line is drawn and should touch the triangle or T-square lightly so as not to press the blades together and thereby change the width of the line; the pen must not be tipped outward, however, as the danger of blotting is greatly increased when the line is drawn so close to the guide.

Sharpening the Drawing Pen. When it is impossible to make a smooth line with the drawing pen, it should be sharpened. Screw the blades together and grind them to a parabolic shape by drawing the pen back and forth over a small, flat, close-grained oilstone. This process, of course, makes the blades dull but insures their being of the same length. Now separate the points slightly and rub one of them on the oilstone, keeping the pen at an angle of from 10° to 15° with the face of the stone, and giving it a slight twisting movement. This part of the operation requires great care as the shape of the ends must not be altered. After one point has become fairly sharp, grind the other in a similar manner, grinding always on the *outside* of the blades and removing the burr from the inside with leather or pine wood. Test the pen by filling with ink and drawing several lines. Unless the lines are smooth, the grinding must be continued.

Ink. India ink is always used for drawing as it makes a permanent black line; it is obtainable in solid stick or liquid form. The liquid form is much more convenient but contains acid which corrodes steel and makes it necessary to keep the pen perfectly clean.

To prepare the ink in stick form for use, put a little water in a saucer and place one end of the stick in it; then by a twisting motion grind enough ink to make the water black and slightly thickened. Now draw a heavy line on a sheet of paper and if after drying the line has a grayish appearance, more grinding is necessary. Wipe the stick dry after using to prevent crumbling. It is well to grind the ink in small quantities as it does not dissolve readily a second time, however, if covered it will keep for two or three days.

Scales. The scales used for obtaining measurements on drawings are made in several forms, the most convenient being the *flat*, with beveled edges, and the *triangular*. The scale is usually graduated for a distance of 12 inches. The triangular scale, Fig. 30, has six

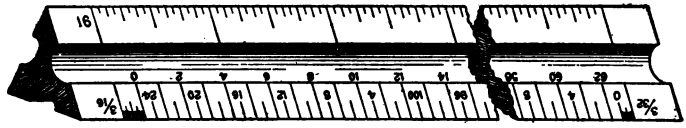


Fig. 30. Triangular Scale

surfaces for different graduations, and the scales are arranged so that the drawings may be made in any proportion to the actual size. For mechanical work, the common divisions are multiples of two; thus drawings are made full size, $\frac{1}{2}$ size, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$, etc. If a drawing is $\frac{1}{4}$ size, 3 inches equals 1 foot, hence 3 inches is divided into 12 equal parts and each division represents one inch. If the smallest division on a scale represents $\frac{1}{16}$ inch, the scale is said to read to $\frac{1}{16}$ inch.

Scales are often divided into $\frac{1}{10}$, $\frac{1}{20}$, $\frac{1}{30}$, $\frac{1}{40}$, etc., for architects and civil engineers, and for measuring indicator cards.

The scale should never be used as a substitute for the triangle or T-square in drawing lines.

Protractor. The protractor, an instrument used for laying off and measuring angles, is made of steel, brass, horn, or paper. When

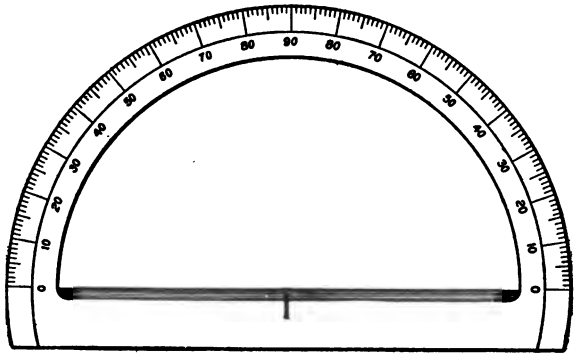


Fig. 31. Protractor

made of metal the central portion is cut out, Fig. 31, so that the draftsman may see the drawing. The outer edge is divided into degrees

and tenths of degrees. To lay off the required angle—use a very sharp, hard pencil in order that the measurements may be accurate—place the protractor so that the two zero marks are on the given line, produced, if necessary, and the center of the circle is at the point through which the desired line is to be drawn.

Irregular Curve. One of the conveniences of a draftsman's outfit is the *French* or *irregular curve,* which is used for drawing curves other than arcs of circles, with either pencil or line pen. This instrument, which is made of wood, hard rubber, or celluloid—celluloid being the best—is made in various shapes, one of the most common being shown in Fig. 32. Curves drawn with an irregular curve are called *free hand curves.*

To draw a curve through a series of located points find that position of the irregular curve that passes through three points,

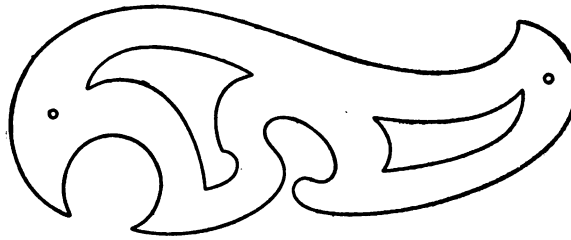


Fig. 32. Typical Irregular Curve

say, and draw the line through them, Fig. 33. Now shift the curve so as to include a part of the curve already drawn and two or three more points. Draw the curve through these points, continuing this process until the curve is completed. If, at each new setting, the line is not carried quite as far as the coincidence of the irregular curve would permit, a smoother curve will result. It frequently facilitates the work and improves its appearance to draw a pencil curve free hand through the points and then use the irregular curve, taking care that it always fits at least *three* points. In inking the curve, the blades of the pen must be kept tangent to the curve. For certain kinds of work, irregular curves of plastic metal are sometimes used to fit exceptionally erratic curves.

Beam Compasses. The ordinary compasses are suitable for drawing circles up to 8 or 10 inches diameter. For larger circles beam compasses are provided. The two parts called *channels*

which carry the pen or pencil and the needle point are clamped to a wooden beam at a distance equal to the radius of the circle. The

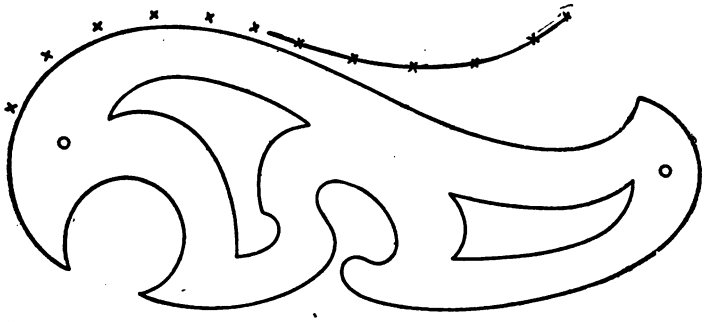


Fig. 33. Method of Using Irregular Curve

thumb nut underneath one of the channel pieces makes accurate adjustment possible.

LETTERING

No mechanical drawing is finished unless all headings, titles, and dimensions are lettered in plain, neat type. Many drawings are accurate, well-planned, and finely executed but do not present a good appearance because the draftsman did not think it worth while to letter carefully. Lettering requires time and patience especially for the beginner; and many think it a good plan to practice lettering before commencing drawing. Poor writing need not necessarily mean poor lettering, for good writers do not always letter well.

In making large letters for titles and headings it is often necessary to use drawing instruments and mechanical aids, but small letters, such as those used for dimensions, names of materials, dates, etc., **should be made free-hand.**

Forming. The student is apt to think that lettering is a form of mechanical drawing, that the use of the straight-edge is the principal operation, and that letters, forms, and the spaces between are to be figured out by measurement. On the contrary, lettering is design, and the draftsman so distributes the letters in the spaces arranged for them as to make a combination that will be pleasing to the eye. The requirements for a good design are simplicity and uniformity. These are acquired by accuracy in detail and by good judgment and taste, as no practical rules can be followed which will

invariably produce the same result. Letter forms are, to a certain extent, standard. The lettering for a title is usually done very carefully and accurately, while practically all of the other lettering on a drawing is done rapidly and in a simple style. To develop a letter use the same method of procedure as in drawing a straight line between two points. First, draw the guide lines rather carefully and then block out the general form of the letter by a series of short strokes of the pencil. Continue this method, straightening the lines and rounding the curves of the latter until its form is satisfactory.

Spacing. The spacing of the letters is very important and is best obtained by the unaided eye just as are the proportions of the letters. Care must be taken to allow a clear distance between letters, the space varying according to the combination. For instance, such letters as *A*, *V*, and *W* spread more at one part than at another and therefore do not fill the space completely. Of course, when the distance between letters is large any such irregularities will not be noticeable. The best method for obtaining good space values is by sketching in the letters roughly and then bringing them to a good appearance by correction and adjustment. The first results are, of course, unsatisfactory, but after the eye and hand have become trained, great improvement will be noticed. A simple aid to this development will be found in the use of a piece of cardboard with the widths of the enclosing rectangles or parallelograms of the different letters marked on its edge, by which the spacing made by the eye may be checked.

Inking. In practical work most of the lettering is penciled in and then finished in ink. As faults in letters which may not be noticed in the penciled work stand out clearly after inking, it is not advisable to ink in the penciled letter accurately, but rather to improve upon it.

For lettering free-hand, use a pen that will make the full weight of line desired without much pressure, holding it squarely on the paper and directly in front. A new pen, which is apt to give too fine a line, may be remedied by scratching a little on a rough surface. If a pen is kept clean and all hardened ink removed so that the nibs are not spread, the pen will last a long time. A coarser pen must be used on rough than on smooth paper.

To remove a faulty line or a blot, let the ink dry thoroughly,

then with a sand rubber, erase the spot carefully, rubbing around it, as well. Clean the sand out of the surface with a pencil eraser and finally polish down with a piece of ivory or smooth wood. Pencil in the parts erased as if doing the work for the first time and again ink in, using special care, as the ink is more likely to spread on an erased surface than anywhere else.

Style. There are many styles of letters used by draftsmen, but almost any neat letter free from ornamentation is acceptable in regular practice. For titles, large Roman capitals are preferred, although Gothic and black letters also look well and are much easier to make. The vertical and inclined or italicized Gothic capitals shown in Fig. 34 and Fig. 35, are neat, plain, and easily made. This

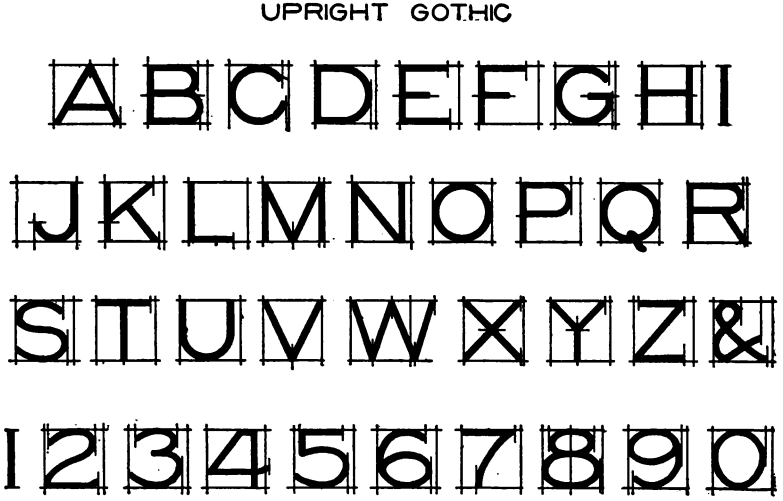


Fig. 34. Upright Gothic Capitals

latter style possesses the advantage over the vertical type in that a slight difference in inclination is not apparent.

The curves of the inclined Gothic letters such as those in *B*, *C*, *G*, *J*, etc., are somewhat difficult to make free-hand, especially if the letters are about one-half inch high. In the alphabet, Fig. 36, the letters are made almost wholly of straight lines, the corners only being curved.

The first few plates of this work will require no titles, the only lettering being the student's name, the date, and the plate number

which will be done in inclined Gothic capitals. Later the subject of lettering will again be taken up in connection with titles and headings for drawings which show the details of machines.

To make the inclined Gothic letters, first draw two parallel lines $\frac{5}{32}$ inch apart to mark the height for the letters of the date, name,

Fig. 35. Inclined Gothic Capitals

and plate number. This is the height to be used on all plates throughout this work, unless other directions are given. When two sizes of letters are used, the smaller should be about two-thirds as high as the larger. The inclination of the letters should be the same for all,

Fig. 36. Inclined Gothic Capitals— Straight Lines with Curved Corners

and as an aid to the beginner, light pencil lines may be drawn about $\frac{1}{4}$ inch apart, forming the proper angle with the parallel lines already drawn; this angle is usually about 70°, but if a 60° triangle is at hand, it may be used in connection with the T-square as shown in Fig. 38.

Capital letters such as *D*, *E*, *F*, *L*, *Z*, etc., should have their top and bottom lines coincide with the horizontal guide lines, as otherwise the work will look uneven. Letters, of which *C*, *G*, *O*, and *Q* are types, may be formed of curved or straight lines. If made of

curved lines, their height should be a little greater than the guide lines to prevent their appearing smaller than the other letters. In this work they may be made of straight lines with rounded corners as such letters are easily constructed and may be made of standard height.

To construct the letter *A*, use one of the 60° lines as a center line. Then from its intersection with the upper horizontal line drop a perpendicular to the lower guide line. Draw another line from the vertex meeting the lower guide line at the same distance on the other side of the center line. The cross line of the *A* should be a little below the center. The *V* is an inverted *A* without the cross line. For the letter *M*, the side lines should be parallel and about the same distance apart as the guide lines. The side lines of the *W* are *not* parallel but are farther apart at the top. The *J* is not quite as wide as such letters as *H*, *E*, *N*, *R*, etc. To make a *Y*, use the same spread as in making a *V* but let the diverging lines meet the center line a little below the middle.

The lower-case letters are shown in Fig. 37. In such letters

Fig. 37. Inclined Gothic Lower-Case Letters

as *m*, *n*, *r*, etc., make the corners slightly rounding. The letters *a*, *b*, *c*, *e*, *g*, *o*, *p*, *q*, should be full and rounding.

The style of the Arabic numerals is given in Fig. 36; Roman numerals are made of straight lines.

At first the copy should be followed closely and the letters drawn in pencil; the inclined guide lines may be used until the proper inclination becomes firmly fixed in mind when they should be abandoned. The horizontal lines, however, are used at all times by most draftsmen. After considerable practice has been had the letters may be constructed in ink without first using the pencil. When proficiency has been attained in the simple inclined Gothic capitals, the vertical, block and Roman alphabets should be studied.

HOW TO HOLD DRAWING INSTRUMENTS

Position of Hand and Instruments. To the student who is just starting out with his drawing work, the position in which he holds his instruments and the free and easy posture of his hands are very important. Just as in playing the piano or in any other process where manual dexterity is required, this skill can only be attained by practice. The following studies should be used in connection with

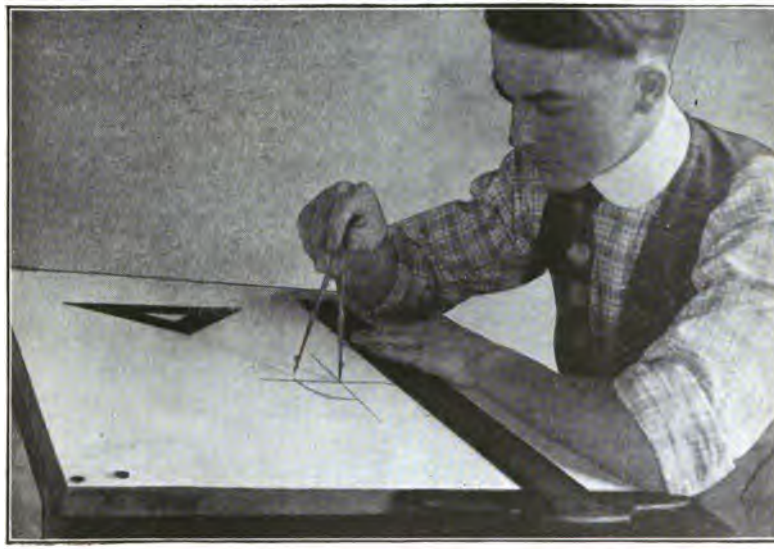
Correct Incorrect Incorrect

Position 1. Right Line Pen against T-Square or Triangle

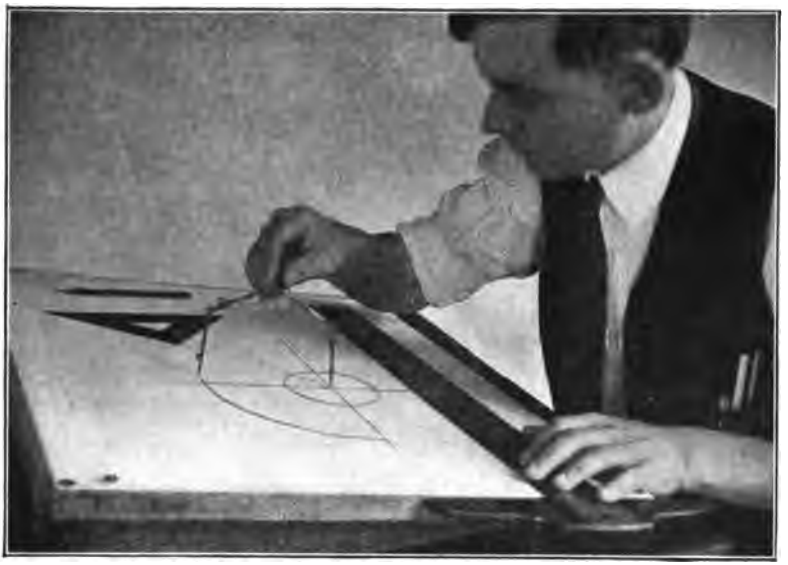
the instructions given in the forepart of this book and wherever references have been given to this section, it is expected that the student will study these plates so as to receive helpful suggestions in his work. In developing skill in Mechanical Drawing, practice is the only method of achieving results after the fundamental principles have been mastered. A very useful collection of "DON'TS" is given herewith and these will bear very close study.

Position 2. Drawing Pencil Line with T-Square and Triangle

Position 3. Inking a Line with Pen and T-Square

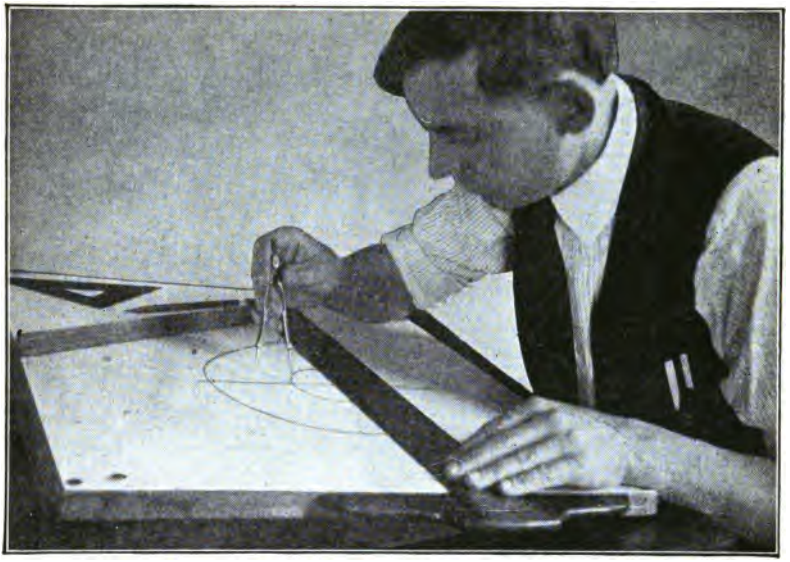


Position 4. Drawing Small Circle with the Compass



Position 5. Drawing Large Circle with Compass with Bent Legs

Position 6. Drawing Very Large Circle with Spread Compass and Lengthening Bar



Position 7. Adjusting Dividers with One Hand. Note Second and Third Fingers between Legs

"DON'TS" IN DRAFTING WORK

Don't fold a drawing.
Don't stick the dividers into the drawing board.
Don't use the dividers as picks.
Don't use the scale to rule lines.
Don't fail to clean the table, board, and instruments when beginning work.
Don't draw on the lower edge of the T-square.
Don't cut the sheets of drawing paper with the upper edge of the T-square and a knife; use the lower edge.
Don't put the end of a pencil in the mouth.
Don't oil the compass joints.
Don't put away the instruments without cleaning, especially pens.
Don't use the cheapest materials.
Don't use the T-square as a hammer.
Don't screw up the nibs of the pen too tight.
Don't use a blotter on lines that have been inked.
Don't run the pen or pencil backward over a line.
Don't fill a pen over a drawing.

PRELIMINARY LINE PROBLEMS

To lay out the paper for the plates of this work, place a sheet *A B G F*, Fig. 38, on the drawing board 2 or 3 inches from the left-hand edge, called the *working edge*. If placed near the left-hand edge, the T-square and triangles can be used with greater firmness and the horizontal lines drawn with greater accuracy. In fastening the paper on the board, always true it up with the T-square according to the long edge of the sheet and use at least 4 thumb tacks —one at each corner. If the paper has a tendency to curl, 6 or 8

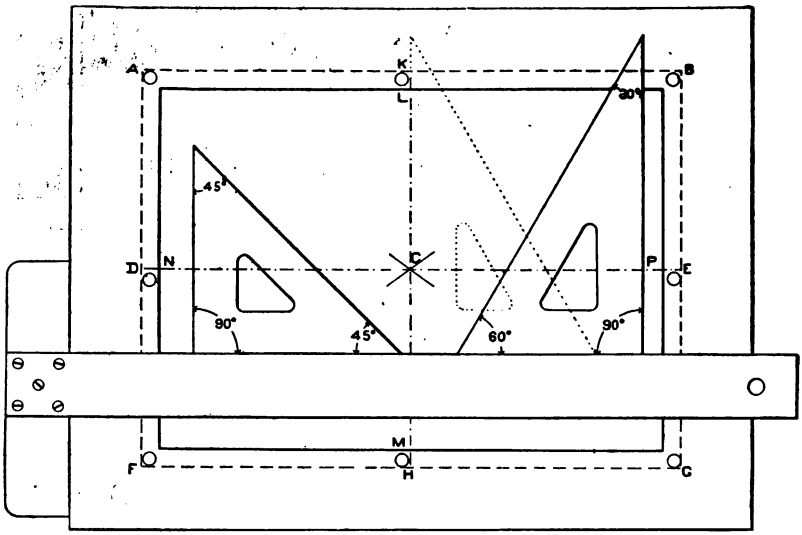


Fig. 38. Standard Lay-Out for Plates

tacks may be used placing them as shown in Fig. 38; many draftsmen prefer one-ounce tacks as they offer less obstruction to the T-square and triangles.

To find the center of the sheet place the T-square so that its upper edge coincides with the diagonal corners *A* and *G* and with the corners *F* and *B*, and draw short pencil lines intersecting at *C*. Now with the T-square draw through the point *C* the dot and dash line *D E*, and with the T-square and one of the triangles—shown dotted in Fig. 38—draw the dot and dash line *H C K*. It will probably be necessary to draw *CK* first and then by means of the T-square or triangle, produce (extend) *CK* to *H*. In this work always move

the pencil from left to right or from the bottom upward; except in certain cases.

After the center lines are drawn measure off 5 inches above and below the point C on the line $H\ C\ K$. These points L and M may be indicated by a light pencil mark or by a *slight* puncture by means of one of the points of the dividers. Now place the T-square against the left-hand edge of the board and draw horizontal pencil lines through L and M.

Measure off 7 inches to the left and right of C on the center line $D\ C\ E$ and draw pencil lines through these points N and P, perpendicular to DE. These lines form a rectangle 10 inches by 14 inches, in which all the exercises and figures are to be drawn. The lettering of the student's name and address, date, and plate number are to be placed *outside* of this rectangle in the $\frac{1}{2}$-inch margin. In all cases lay out the plates in this manner and keep the center lines $D\ E$ and $K\ H$ as a basis for the various figures. Ink in the border line with a heavy line when the drawing is finished.

Penciling. In laying out the first few plates of this course the work is to be done in pencil and then inked in; later the subject of tracing the pencil drawings on tracing cloth and the process of making blue prints from these tracings will be taken up. Every beginner should practice with his instruments until he understands them thoroughly and can use them with accuracy and skill. To aid the beginner in this work, the first three plates of this course are practice plates; they do not involve any problems and none of the work is difficult. The student is strongly advised to draw these plates two or three times before making the one to be sent to us for correction. Diligent practice is necessary at first; especially on *Plate I* as it involves an exercise in lettering.

Inking. To ink a drawing well requires great care and some experience. The student should not attempt to ink in his work until he can make a clear-cut, straight line with ease. It is well to practice inking in straight pencil lines, rectangles, and triangles in order to improve the work on lines, corners, and intersections. These latter should be very definite, each line stopping at exactly the right point.

Before starting to ink in, adjust the pen by means of the thumb screw until a good clear line of the desired width is obtained, making frequent test lines, on a piece of material similar to that which is to

be used. Keep the pressure of the pen on the paper uniformly light, remembering that different weights of lines are not obtained by pressure as with the ordinary writing pen but only by adjusting the nibs of the pen. If the lines are ragged the pen should be put in order, according to the instructions already given. Sometimes when the ink does not flow regularly, moisten the end of the finger and touch the point of the pen. Care should be taken not to put too much ink in the pen, but on the other hand there must be enough to draw the next line as it is difficult to continue a line after re-filling the pen. The only way to draw fine lines well is to frequently clean and re-fill the pen. If the amount of ink in the pen is small it is quite likely to thicken in the point and cause clogging. When this occurs, draw a small strip of paper between the nibs to clean out the clogged ink.

When drawing, the pen should be held with the thumb screw out and should be inclined slightly in the direction in which it is moved. Be careful, however, not to incline it too much, as the best of pens when incorrectly held will produce poor lines. It is therefore advisable at the start to acquire the correct method of holding the pen. Do not press the sides of the pen point too heavily against the ruling edge as this will vary the width of the line; after a little practice the pen can be lightly and firmly brought in contact with the paper and ruling edge at the same time. The pen should be drawn from left to right, the hand being steadied by sliding it on the end of the little finger.

Always try to get into the easiest position when inking a line, even if it becomes necessary to walk around the drawing. The average draftsman prefers the standing position while inking as he can usually obtain much better results. Keep the ruling edge between the line and the body so that the pen will be drawn against the ruling edge, for if this is not done, the pen is liable to be pulled off at an angle, making a crooked line. Be careful after inking a line to draw the ruling edge toward the body away from the line in order to avoid blotting. Where lines meet at a point, always ink towards the point, being sure to allow one line to dry before inking another. Always ink in the top and left-hand lines first, gradually working down to the right, thus saving time that otherwise would be lost in waiting for the lines to dry. When the pen is set at the proper width, draw all the lines of that width before making a change. Never push

the pen backward over a line. If a good line is not drawn the first time, it is better to go over it again in the same direction, taking great care not to widen the original line.

Ink dries very quickly and should not be left in the pen on account of its corrosive effects. The celluloid triangles should be washed frequently in water and all ink spots removed.

In using the compass, bend both legs so that each will be perpendicular to the paper or cloth when the arc or circle is drawn. When the pen attachment is used special care must be exercised on this point for in no other way can the nibs of the pen be made to bear evenly on the surface. In drawing arcs, hold the cylindrical handle at the top of the compass loosely between the thumb and the forefinger and let it roll between the two during rotation; allow the compass to lean slightly in the direction of rotation, pressing down the pen point slightly but not the needle point. Be sure to fix the needle point firmly in its proper place on the paper before touching the pen to the paper, as otherwise a slip is likely to occur. In setting the needle down on any particular center, guide it with a finger of the left hand. Avoid making a noticeable hole in the paper.

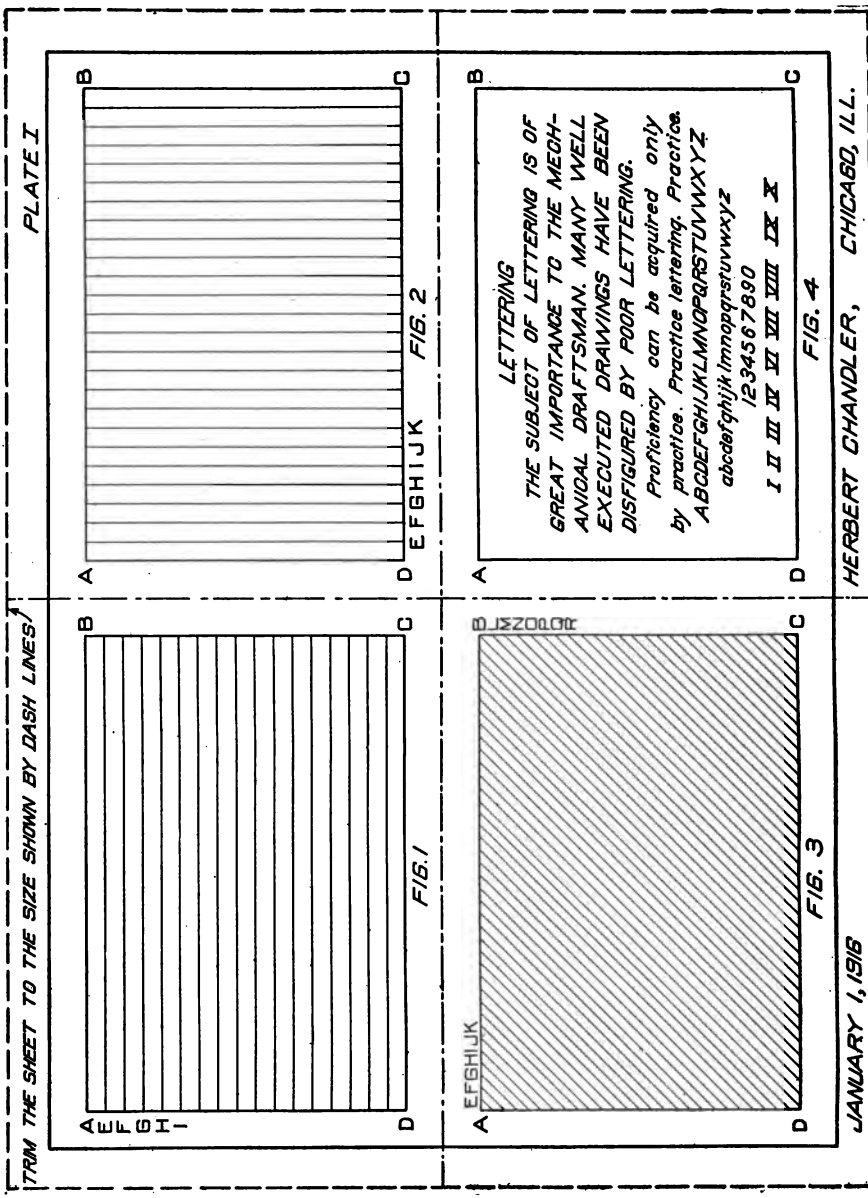
Ink in the circumference of a circle with one continuous motion, giving an even pressure to the pen throughout the operation and stopping it sharply at the end of one revolution. Since straight lines can be more easily drawn tangent to curves than the reverse, it is always advisable to ink in all arcs or circles first. When a number of circles are to be drawn from one center, the smaller should be inked first while the center is in the best possible condition.

PLATE I

Penciling. To draw *Plate I*,* take a sheet of drawing paper at least 11 inches by 15 inches and fasten it to the drawing board as already explained. Find the center of the sheet and draw fine pencil lines to represent the lines *DE* and *HK* of Fig. 38. Also draw the border lines *L*, *M*, *N*, and *P*.

Now measure $\frac{3}{8}$ inch above and below the horizontal center line and, with the T-square, draw lines through these points. These lines will form the lower lines *DC* of Fig. 1 and Fig. 2 and the top lines *AB* of Fig. 3 and Fig. 4. Measure $\frac{3}{8}$ inch to the right and left

*Note Instructions, pages 22 to 25, inclusive.


TRIM THE SHEET TO THE SIZE SHOWN BY DASH LINES
PLATE I
A B C D
E F G H I
FIG. 1
A B C D
E F G H I J K
FIG. 2
A B C D
EFGHIJK
FIG. 3
A B C D
LETTERING
THE SUBJECT OF LETTERING IS OF GREAT IMPORTANCE TO THE MECHANICAL DRAFTSMAN. MANY WELL EXECUTED DRAWINGS HAVE BEEN DISFIGURED BY POOR LETTERING.
Proficiency can be acquired only by practice. Practice lettering.
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890
I II III IV V VI VII VIII IX X
FIG. 4
JANUARY 1, 1918
HERBERT CHANDLER, CHICAGO, ILL.

of the vertical center line; and through these points, draw lines parallel to the center line. These lines should be drawn by placing the triangle on the T-square as shown in Fig. 38. The lines thus drawn, form the sides *B C* of Fig. 1 and Fig. 3 and the sides *A D* of Fig. 2 and Fig. 4. Next draw, with the T-square, the line *A B A B* $4\frac{5}{8}$ inches above the horizontal center line, and the line *D C D C* $4\frac{5}{8}$ inches below the horizontal center line. The rectangles of the four figures may now be completed by drawing vertical lines $6\frac{5}{8}$ inches on each side of the vertical center line; these rectangles are each $6\frac{1}{4}$ inches long and $4\frac{1}{4}$ inches wide.

Fig. 1. *Exercise with Line Pen and T-square.* Divide the line *A D* into divisions each $\frac{1}{4}$ inch long, making a fine pencil point or *slight* puncture at each division such as *E, F, G, H, I,* etc. Now place the T-square with its head at the left-hand edge of the drawing board and through these points draw light pencil lines extending to the line *B C.* In drawing these lines the pencil point must pass *exactly* through the division marks so that the lines will be the same distance apart. Start each line in the line *A D* and do not fall short of the line *B C* or run over it. Accuracy and neatness in penciling insure an accurate drawing. Some beginners think that they can correct inaccuracies while inking; but experience soon teaches them that they cannot do so.

Fig. 2. *Exercise with Line Pen, T-square and Triangle.* Divide the lower line *D C* of the rectangle into divisions each $\frac{1}{4}$ inch long and mark the points *E, F, G, H, I, J, K,* etc., as in Fig. 1. Place the T-square about as shown in Fig. 38, and either triangle in position with its 90-degree angle at the left. Now draw fine pencil lines from the line *D C* to the line *A B* passing through the points *E, F, G, H, I, J, K,* etc., keeping the T-square rigid and sliding the triangle toward the right.

Fig. 3. *Exercise with Line Pen T-square and 45-degree Triangle.* Lay off the distances *A E, B L,* etc., each $\frac{1}{4}$ inch long on *A B* and *B C,* respectively. Place the T-square so that the upper edge will be below the line *D C,* and, with the 45-degree triangle, draw the diagonal lines through the points laid off. In drawing these lines move the pencil away from the body, *i. e.,* from *A D* to *A B* and from *D C* to *B C.*

Fig. 4. *Exercise in Free-Hand Lettering.* Draw the center line *E F,* Fig. 39, and light pencil lines *Y Z* and *T X,* $\frac{3}{8}$ inch from the

border lines. With the T-square, draw the line G, $\frac{1}{4}$ inch from the top line and the line H, $\frac{5}{32}$ inch below G. The word "*LETTERING*" is to be placed between these two lines. Draw the line I, $\frac{3}{16}$ inch below H, and space the lines included between I and K, $\frac{5}{32}$ inch apart.

The next style of letters to be discussed is lower-case letters. Draw the line L $\frac{9}{16}$ inch below K and to limit the height of the small letters draw a light line $\frac{1}{8}$ inch above L.

Make the space between L and M, $\frac{5}{32}$ inch and draw M and N in the same manner as K and L. Now draw O, $\frac{3}{16}$ inch below N,

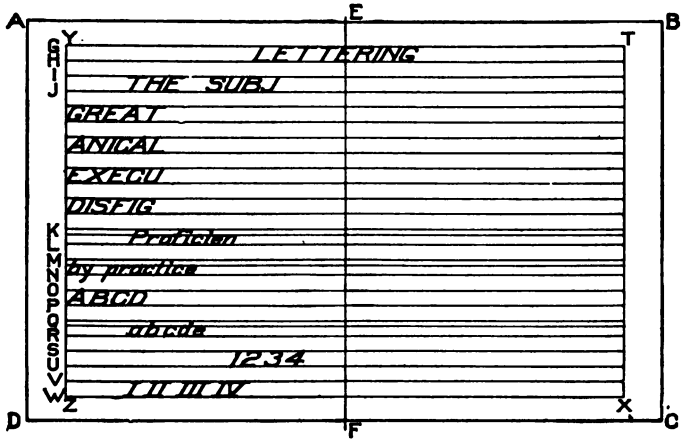


Fig. 39. Sample Lettering Plate—Fig. 4., Plate I

P, $\frac{5}{32}$ inch below O, and Q, $\frac{5}{32}$ inch below P. Space Q and R as K and L, and draw S, U, V, and W, $\frac{5}{32}$ inch apart.

The center line is a great aid in centering the word "*LETTERING*," the alphabets, numerals, etc. Indent the words "*THE*" and "*Proficiency*" about $\frac{3}{8}$ inch, as they are the first words of paragraphs. To draw the guide lines, mark off distances of $\frac{1}{4}$ inch on any line such as J and with the 60-degree triangle draw light pencil lines cutting the parallel lines. Sketch the letters in pencil making the width of the ordinary letters such as E, F, H, N, R, etc., about $\frac{3}{4}$ their height. Letters like A, M, and W, are wider. The space between the letters depends upon the draftsman's taste, but the beginner should remember that letters next to an A or an L should be placed nearer to them than to letters whose sides are parallel; for

instance there should be more space between an *N* and *E* than between an *E* and *H*. Similarly a greater space should be left on either side of an *I*. On account of the space above the lower line of the *L*, a letter following an *L* should be close to it. If a *T* follows a *T* or an *L* follows an *L* place them near together. In all lettering place the letters so that the general effect is pleasing. After the four figures are completed, pencil in the lettering for name, address, and date. With the T-square draw a pencil line $\frac{5}{32}$ inch above the top border line at the right-hand end, and about 3 inches long. At a distance of $\frac{5}{32}$ inch above this line draw another line of about the same length. These are the guide lines for the word *Plate I*. Pencil the letters free-hand using the 60-degree guide lines if desired.

Draw in a similar manner the guide lines of the date, name, and address in the lower margin, the date of completing the drawing placed under Fig. 3, and the name and address at the right, under Fig. 4. The street address is unnecessary. It is a good plan to draw lines $\frac{5}{32}$ inch apart on a separate sheet of paper and pencil the letters in order to know just how much space each word will require. The insertion of the words "Fig. 1," "Fig. 2," etc., is optional with the student, but it is advised that he do this extra lettering for the practice as well as for convenience in reference. First draw with the T-square two parallel lines $\frac{5}{32}$ inch apart under each exercise, the lower line being $\frac{1}{16}$ inch above the horizontal center line or above the lower border line.

Inking. After all of the penciling of *Plate I* has been completed the exercises should be inked. Before doing this, however, see that the pen is in proper condition, and after filling try it on a separate piece of paper in order that the proper width of line may be drawn. In the first work where no shading is done, use a firm, distinct line. The beginner should avoid the extremes; a very light line makes the drawing appear weak and indistinct, while a very heavy line detracts from its artistic appearance.

Ink in all the horizontal lines of Fig. 1 first, moving the T-square from *A* to *D*, and take great care to start and stop the lines exactly on the vertical boundary lines. It is necessary to use both triangle and T-square for inking *A D* and *B C*. In inking Fig. 2 and Fig. 3, follow the same directions as for penciling, inking in the vertical and oblique lines first and then the border lines. Ink the border lines

of Fig. 4 first and then the border lines of the plate, making the latter very heavy and the intersections accurate. The lettering in Fig. 4 should be done free-hand, using a steel pen not finer than a Gillott 404. Now ink in the four figure numbers, plate number, date, and name, also free-hand, and then erase the pencil lines. **In the finished drawing there should be no center lines, construction lines, or letters other than those in the name, date, etc.**

Cut the sheet 11″ × 15″, the dash line outside the border line of *Plate I* indicating the edge.

PLATE II

Penciling. The horizontal and vertical center lines and the border lines for *Plate II* are laid out in the same manner as were those of *Plate I*. To draw the squares for the six figures, proceed as follows:

Measure off two inches on either side of the vertical center line and draw light pencil lines through these points parallel to the vertical center line. These lines will form the sides *A D* and *B C* of Fig. 2 and Fig. 5. Parallel to these lines and at a distance of ½ inch draw similar lines to form the sides *B C* of Fig. 1 and Fig. 4 and *A D* of Fig. 3 and Fig. 6. The vertical sides *A D* of Fig. 1 and Fig. 4 and *B C* of Fig. 3 and Fig. 6 are formed by drawing lines perpendicular to the horizontal center line at a distance of 6½ inches from the center.

Complete the figures by laying off lines ½ inch and 4½ inches above and below the horizontal center line respectively, thus forming six 4-inch squares.

In drawing Fig. 1, divide *A D* and *A B* into 4 equal parts, then draw horizontal lines through *E*, *F*, and *G* and vertical lines through *L*, *M*, and *N*. Draw lines from *A* and *B* to the intersection *O* of lines *E* and *M*, and from *A* and *D* to the intersection *P* of lines *F* and *L*. Similarly draw *D J*, *J C*, *C I*, and *I B*. Also connect the points *O*, *P*, *J*, and *I*, thus forming a square. The four diamond-shaped areas are formed by drawing lines from the middle points of *A D*, *A B*, *B C*, and *D C* to the middle points of lines *A P*, *A O*, *O B*, *I B*, etc., as shown in Fig. 1.

Fig. 2 is an exercise of straight lines. Divide *A D* and *A B* into four equal parts and draw horizontal and vertical lines as in Fig. 1. Now divide these dimensions, *A L*, *M N*, etc., and *E F*,

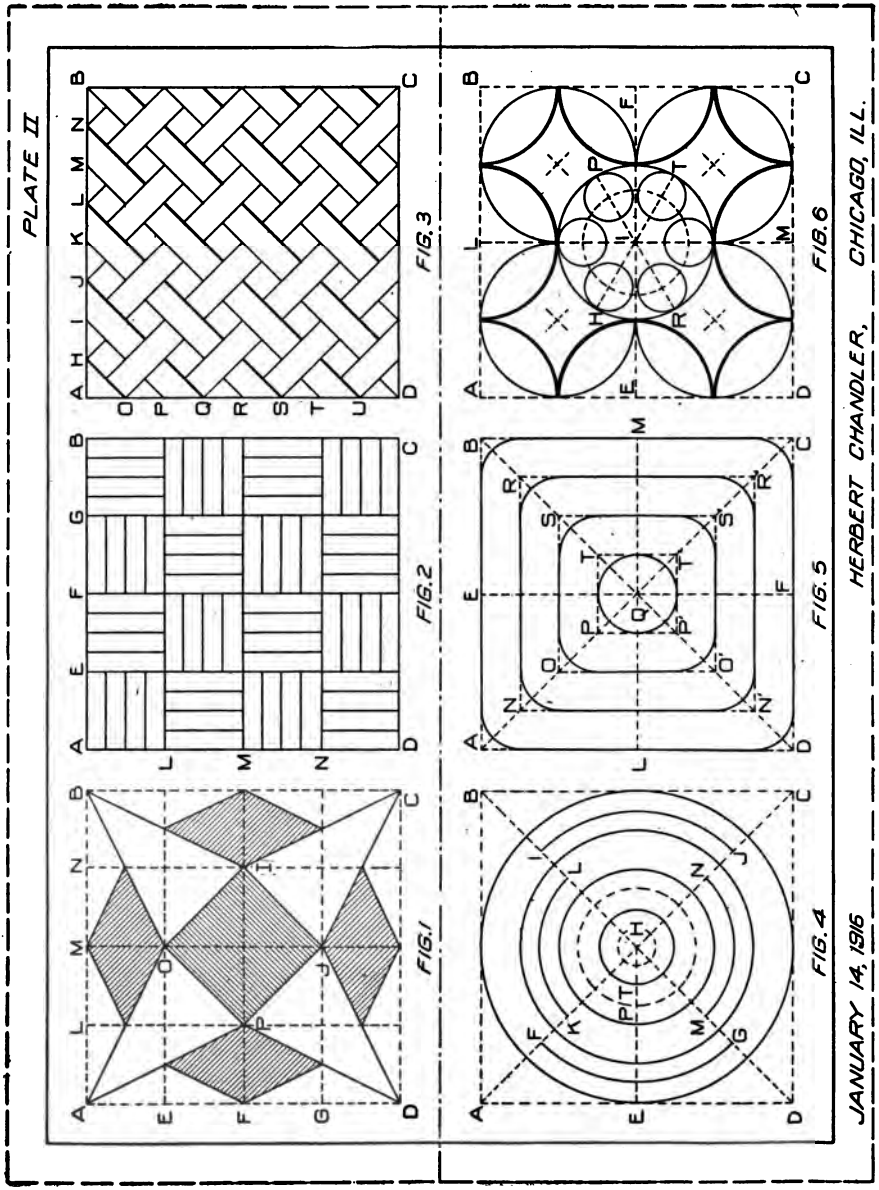


PLATE II
FIG.1
FIG.2
FIG.3
FIG.4
FIG.5
FIG.6
HERBERT CHANDLER, CHICAGO, ILL.
JANUARY 14, 1916

G B, etc., into four equal parts—each $\frac{1}{4}$ inch—and draw light pencil lines with the T-square and triangle as shown.

In Fig. 3, divide *A D* and *A B* into eight equal parts, and through the points *O*, *P*, *Q*, *H*, *I*, *J*, etc., draw horizontal and vertical lines. Now draw lines connecting *O* and *H*, *P* and *I*, *Q* and *J*, etc. As these lines form an angle of 45 degrees with the horizontal, a 45-degree triangle may be used. Similarly from each one of the given points on *A B* and *A D*, draw lines at an angle of 45 degrees to *B C* and *D C* respectively.

Fig. 4 is drawn with the compasses. Draw the diagonals *A C* and *D B*, and with the T-square draw the line *E H*. Now mark off on *E H* distances of $\frac{1}{4}$ inch, and with *H* as a center describe, by means of the compasses, circles having radii respectively 2 inches, $1\frac{1}{2}$ inches, 1 inch, $\frac{3}{4}$ inch, $\frac{1}{2}$ inch, and $\frac{1}{4}$ inch. Similarly with *H* as a center and a radius of $1\frac{3}{4}$ inches and $1\frac{1}{4}$ inches respectively draw the arcs *F G* and *I J* and *K L* and *M N*, being careful to end the arcs in the diagonals.

Fig. 5 is an exercise with the line pen and compasses. Draw the diagonals *A C* and *D B*, the horizontal line *L M* and the vertical line *E F* passing through the center *Q*. Mark off distances of $\frac{1}{2}$ inch on *L M* and *E F* and complete the squares *N R R' N'*, etc. With the bow pencil adjusted so that the distance between the pencil point and the needle point is $\frac{1}{2}$ inch, draw arcs having centers at the corners of the inner squares. The arc whose center is *N* will be tangent to the lines *A L* and *A E* and the arc whose center is *O* will be tangent to *N N'* and *N R*. Since the smallest square has 1 inch sides, the $\frac{1}{2}$-inch arcs drawn with *Q* as a center will form a circle.

In Fig. 6, draw the center lines *E F* and *L M*, and find the centers of the four squares thus formed. Through the center *I* draw the construction lines *H I T* and *R I P* forming angles of 30 degrees with *EF*. Now adjust the compasses to draw circles having a radius of one inch, and with *I* as a center, draw the circle *H P T R*. With the same radius draw the arcs with centers at *A*, *B*, *C*, and *D*, and also draw the semicircles with centers at *L*, *F*, *M*, and *E*. Now draw the arcs as shown having centers at the centers of the four squares. To locate the centers of the six small circles within the circle *H P T R*, draw a circle with a radius of $\frac{11}{16}$ inch and having the center in *I*. The small circles each have a radius of $\frac{5}{16}$ inch.

Inking. In *Plate II* ink in only the lines shown *full* in the specimen plate. First ink the star and then the square and diamonds. As this is an exercise for practice, the cross-hatching should be done *without* measuring the distance between the lines and without the aid of any cross-hatching device. The lines should be about $\frac{1}{16}$ inch apart. After inking in the plate all construction lines should be erased.

In inking Fig. 2 first ink the principal horizontal and vertical lines and then very carefully ink in the short lines. Make these lines all of the same width.

Fig. 3 is drawn entirely with the 45-degree triangle. In inking the oblique lines make *P I*, *R K*, *T M*, etc., of the usual width, while the alternate lines *O H*, *Q J*, *S L*, etc., should be somewhat heavier. All of the lines which slope in the opposite direction are light. Now ink in the border lines and erase all other horizontal and vertical lines.

In inking Fig. 4 use only the compasses, adjusting the legs so that the pen will always be perpendicular to the paper. In inking the arcs, see that the pen stops *exactly* at the diagonals. The inner circle and the next but one should be dotted as shown in the specimen plate. After inking the circles and arcs erase the construction lines that are without the outer circles, leaving in *pencil* the diagonals inside the circles.

In Fig. 5 *draw all arcs first* and then the straight lines meeting these arcs, as it is much easier to make a straight line meet an arc or tangent to it, than the reverse. Leave all construction lines in pencil. This exercise is difficult, and as in all mechanical and machine drawing, arcs and tangents are frequently used, the beginner is advised to draw this exercise several times.

Fig. 6 is an exercise with compasses. If the laying out has been accurately done in pencil, the inked arcs will be tangent to each other and the finished exercise will have a good appearance. If, however, the distances were not accurately measured and the lines carefully drawn, the inked arcs will not be tangent. The arcs whose centers are *L*, *F*, *M*, and *E*, and *A*, *B*, *C*, and *D* should be heavier than the rest. The small circles may be drawn with the bow pen. After inking the arcs all construction lines should be erased.

Finally ink in the figure numbers, the border lines of the plate, name, address, and plate number as in *Plate I*.

PLATE III

Penciling. *Plate III* should be laid out in the same manner as *Plate II*, that is, for size and border lines. In laying out the sixteen rectangles, however, the space between the center lines and rectangles must in every case be made $\frac{1}{2}$ inch. Each rectangle is to be filled in with what is called *section lining*, illustrating the material of which the object is composed, and, therefore, differing accordingly. The conventions here shown are standard, and some of them will be used by the student in later work in Machine Drawing. Familiarity with them is of value to any draftsman. In drawing section lines of this character, the closeness of the lines should be governed by the area being sectioned. For large areas use a rather wide spacing; for small areas use a narrow spacing. In showing a section of any machine, the different parts are distinguished by altering the slope of the section lines, whether of the same material or not.

Draw the sixteen figures in full and then draw the border lines of the plate. Make the lettering conform to that in *Plate I* and *Plate II*.

Inking. After all the penciling of *Plate III* has been completed, the exercise should be inked, including the titles.

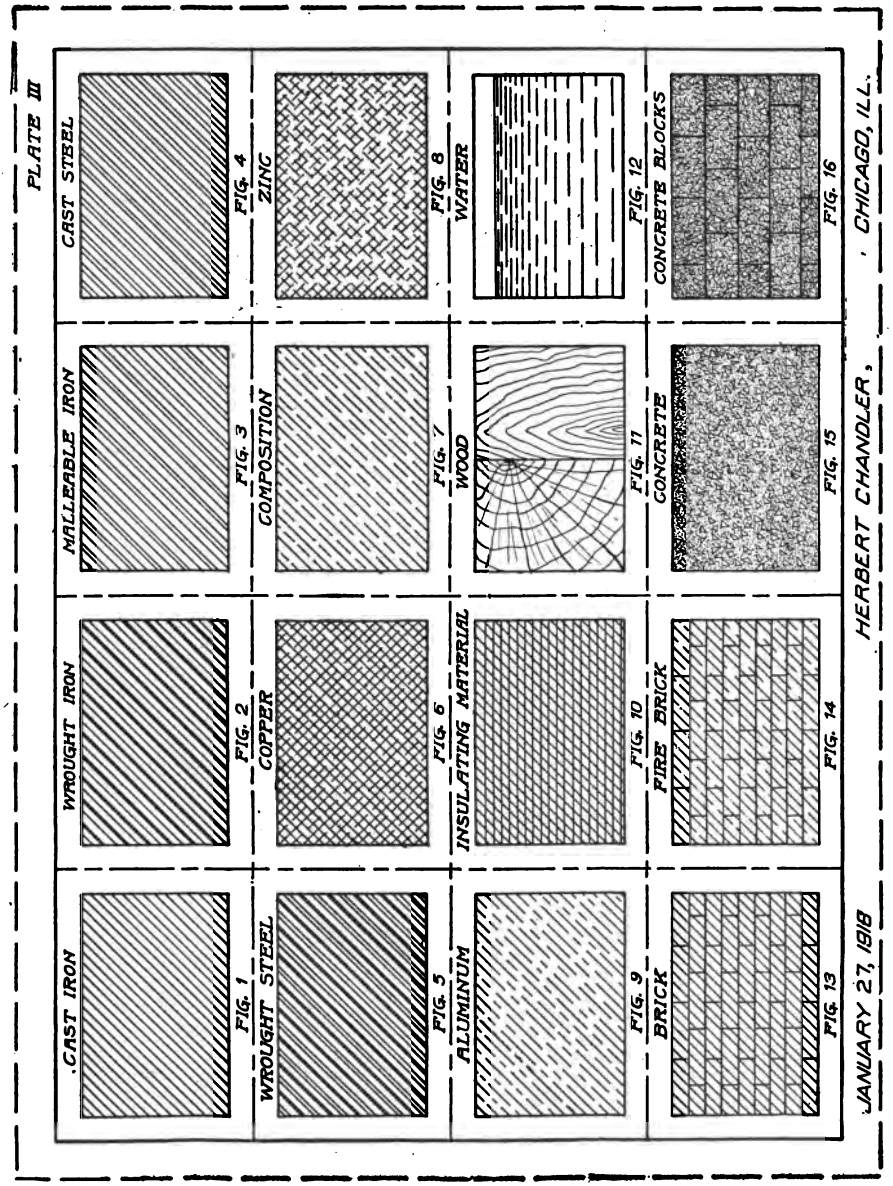
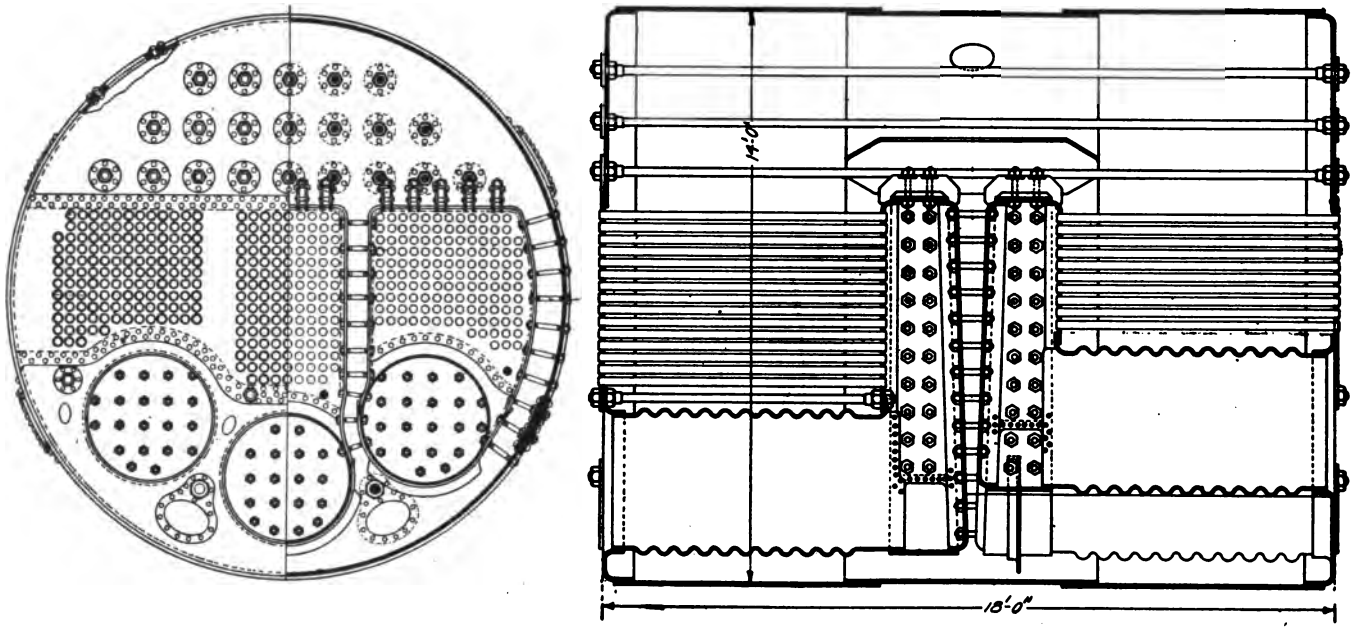
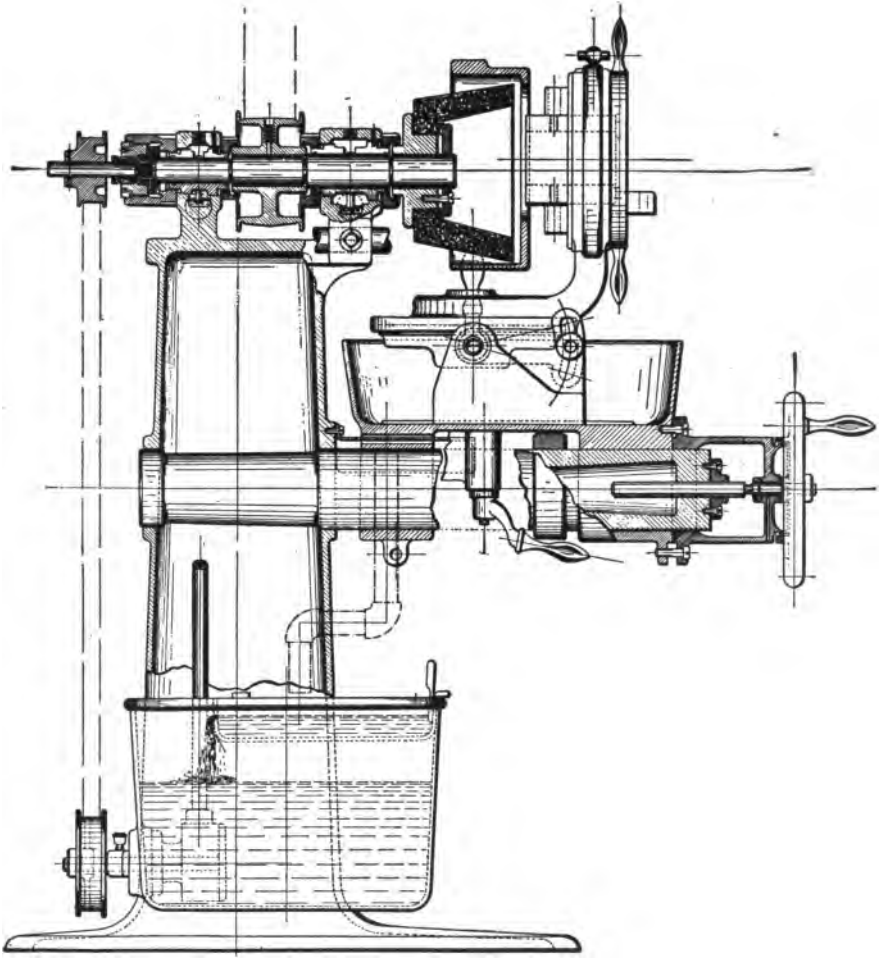


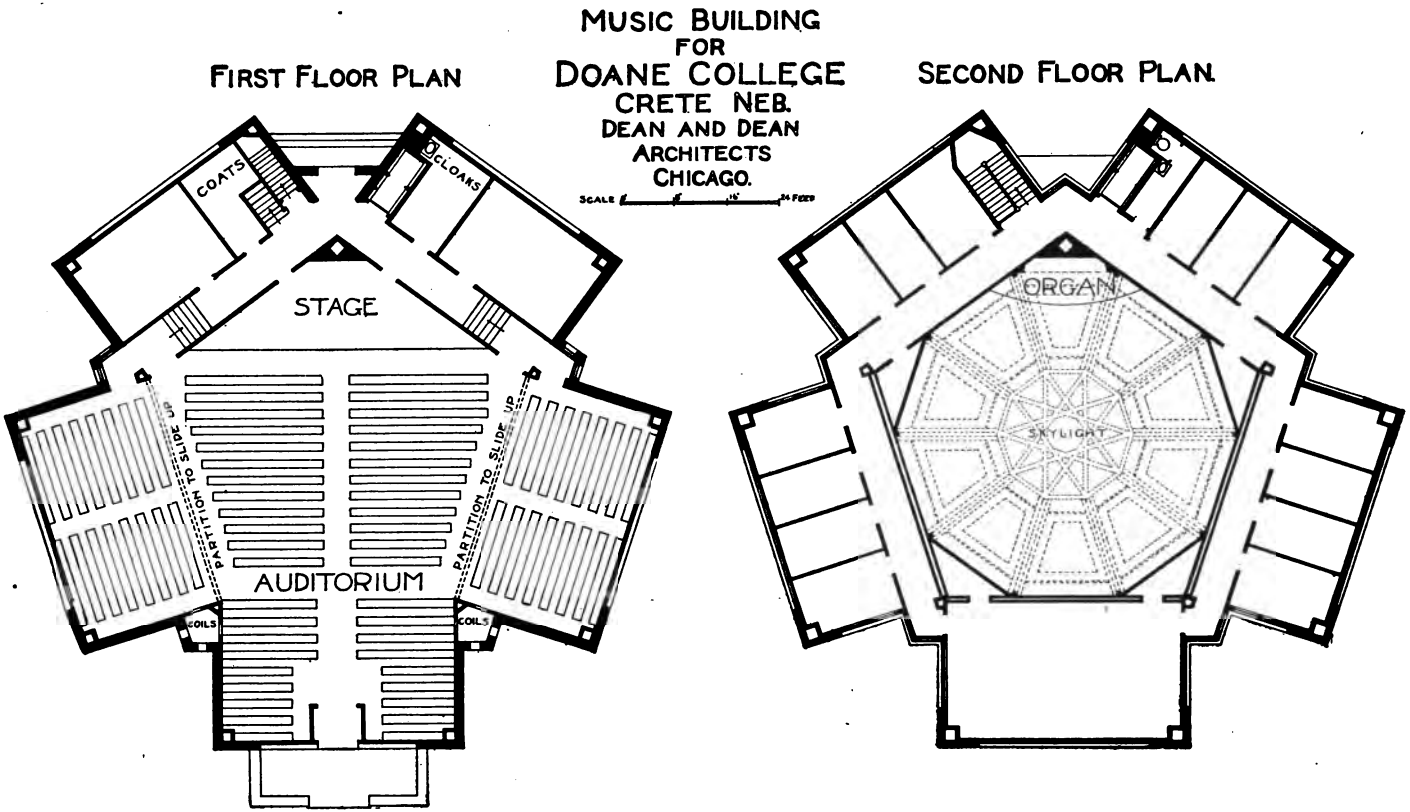
PLATE III
CAST IRON
FIG. 1
WROUGHT STEEL
FIG. 5
ALUMINUM
FIG. 9
BRICK
FIG. 13
WROUGHT IRON
FIG. 2
COPPER
FIG. 6
INSULATING MATERIAL
FIG. 10
FIRE BRICK
FIG. 14
MALLEABLE IRON
FIG. 3
COMPOSITION
FIG. 7
WOOD
FIG. 11
CONCRETE
FIG. 15
CAST STEEL
FIG. 4
ZINC
FIG. 8
WATER
FIG. 12
CONCRETE BLOCKS
FIG. 16
JANUARY 27, 1918
HERBERT CHANDLER,
CHICAGO, ILL.



VERTICAL AND LONGITUDINAL SECTIONS OF 2-FLUE, DOUBLE-ENDED RETURN-TUBE BOILER



GISHOLT TOOL GRINDER
Courtesy of Gisholt Machine Company, Madison, Wisconsin



FIRST AND SECOND FLOOR PLANS OF MUSIC BUILDING FOR DOANE COLLEGE, CRETE, NEBRASKA
Dean and Dean, Architects, Chicago, Illinois
For longitudinal section see opposite page 141. For exterior see page 67.

MECHANICAL DRAWING

PART II

In Part I the instructions and the problems worked out have been designed to teach the student the elementary operations of Mechanical Drawing, giving him a knowledge of the instruments, an ability to draw a straight and true line, and to make up simple figures. A fair degree of drawing ability is now assumed and we can pass on to more complicated problems. Wherever we turn for subjects, however, we find a knowledge of geometrical figures and their properties is absolutely essential to a clear understanding of the problems chosen and we will therefore turn to a discussion of these geometrical figures and the problems which involve them.

GEOMETRICAL DEFINITIONS

A *point* is used for marking position; it has neither length, breadth, nor thickness.

LINES

A *line* has length only; it is produced by the motion of a point.

A *straight line* or *right line* is one that has the same direction throughout. It is the shortest distance between two points.

A *curved line* is one that is constantly changing in direction. It is sometimes called a curve.

A *broken line* is one made up of several straight lines.

Parallel lines are lines which lie in the same plane and are equally distant from each other at all points.

A *horizontal line* is one having the direction of a line drawn upon the surface of water that is at rest. It is a line parallel to the horizon.

A *vertical line* is one that lies in the direction of a thread suspended from its upper end and having a weight at the lower end. It is a line that is perpendicular to a horizontal plane.

An *oblique line* is one that is neither vertical nor horizontal.

In Mechanical Drawing, lines drawn along the edge of the T-square, when the head of the T-square is resting against the left-hand edge of the board, are called *horizontal* lines. Those drawn at right angles or perpendicular to the edge of the T-square are called *vertical* lines.

If two lines cut each other, they are called *intersecting lines*, and the point at which they cross is called the *point of intersection.*

ANGLES

An *angle* is the measure of the difference in direction of two lines. The lines are called *sides*, and the point of meeting, the

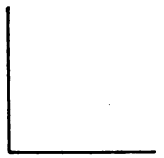


Fig. 40. Right Angle

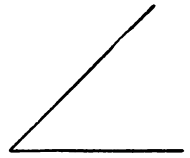


Fig. 41. Acute Angle

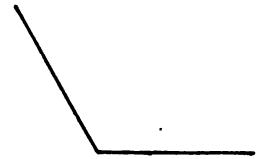


Fig. 42. Obtuse Angle

vertex. The size of an angle is independent of the length of the lines.

If one straight line meets another (extended if necessary), Fig. 40, so that the two angles thus formed are equal, the lines are said to be *perpendicular* to each other and the angles formed are called *right angles.*

An *acute angle* is less than a right angle, Fig. 41.

An *obtuse angle* is greater than a right angle, Fig. 42.

SURFACES

A *surface* is produced by the motion of a line; it has two dimensions—length and breadth.

A *plane figure* is a plane bounded on all sides by lines; the space included within these lines (if they are straight lines) is called a *polygon* or a *rectilinear figure.*

POLYGONS

A *polygon* is a plane figure bounded by straight lines. The boundary lines are called the *sides* and the sum of the sides is called the *perimeter.*

Polygons are classified according to the number of sides.

A *triangle* is a polygon of *three* sides.

A *quadrilateral* is a polygon of *four* sides.

A *pentagon* is a polygon of *five* sides, Fig. 43.

A *hexagon* is a polygon of *six* sides, Fig. 44.

A *heptagon* is a polygon of *seven* sides.

An *octagon* is a polygon of *eight* sides, Fig. 45.

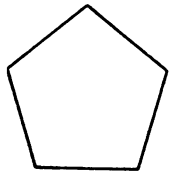


Fig. 43. Pentagon

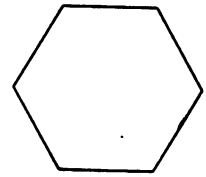


Fig. 44. Hexagon

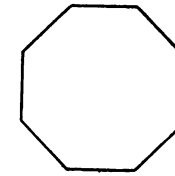


Fig. 45. Octagon

A *decagon* is a polygon of *ten* sides.

A *dodecagon* is a polygon of *twelve* sides.

An *equilateral* polygon is one all of whose sides are equal.

An *equiangular* polygon is one all of whose angles are equal.

A *regular* polygon is one all of whose angles and all of whose sides are equal.

Triangles. A triangle is a polygon enclosed by three straight lines called *sides*. The *angles* of a triangle are the angles formed by the sides.

A *right-angled* triangle, often called a *right* triangle, Fig. 46, is one that has a right angle. The longest side (the one opposite

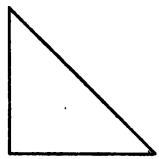


Fig. 46. Right-Angled Triangle

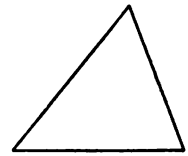


Fig. 47. Acute Angled Triangle

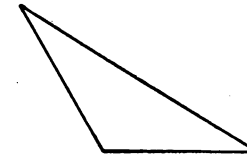


Fig. 48. Obtuse-Angled Triangle

the right angle) is called the *hypotenuse*, and the other sides are sometimes called *legs*.

An *acute-angled* triangle is one that has all of its angles acute, Fig. 47.

An *obtuse-angled* triangle is one that has an obtuse angle, Fig. 48.

An *equilateral* triangle is one having all of its sides equal, Fig. 49.

An *equiangular* triangle is one having all of its angles equal.

An *isosceles* triangle, Fig. 50, is one, two of whose sides are equal.

A *scalene* triangle, Fig. 51, is one, no two of whose sides are equal.

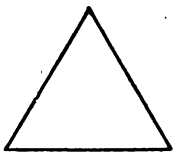


Fig. 49. Equilateral Triangle

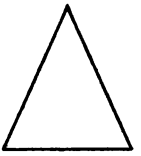


Fig. 50. Isosceles Triangle

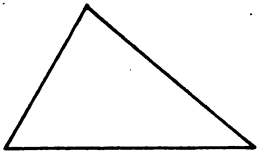


Fig. 51. Scalene Triangle

The base of a triangle is the lowest side; it is the side upon which the triangle is supposed to stand. Any side may, however, be taken as the base. In an isosceles triangle, the side which is not one of the equal sides is usually considered as the base.

The *altitude* of a triangle is the perpendicular drawn from the vertex to the base.

Quadrilaterals. A quadrilateral is a polygon bounded by four straight lines, as Fig. 52.

The *diagonal* of a quadrilateral is a straight line joining two opposite vertices.

Trapezium. A trapezium is a quadrilateral, no two of whose sides are parallel.

Trapezoid. A trapezoid is a quadrilateral having two sides

Fig. 52. Quadrilateral

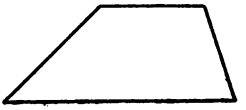


Fig. 53. Trapezoid

Fig. 54. Parallelogram

parallel, Fig. 53. The parallel sides are called the *bases* and the perpendicular distance between the bases is called the *altitude.*

Parallelogram. A parallelogram is a quadrilateral whose opposite sides are parallel, Fig. 54.

There are four kinds of parallelograms: rectangle, square, rhombus, and rhomboid.

The *rectangle,* Fig. 55, is a parallelogram whose angles are right angles.

The *square,* Fig. 56, is a parallelogram all of whose sides are equal and whose angles are right angles.

The *rhombus*, Fig. 57, is a parallelogram whose sides are equal but whose angles are not right angles.

Fig. 55. Rectangle

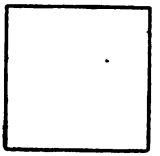


Fig. 56. Square

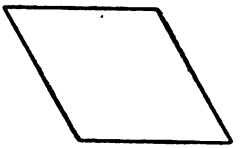


Fig. 57. Rhombus

The *rhomboid* is a parallelogram whose adjacent sides are unequal, and whose angles are not right angles.

CIRCLES

A *circle* is a plane figure bounded by a curved line called the *circumference*, every point of which is equally distant from a point within called the *center*, Fig. 58.

A *diameter* of a circle is a straight line drawn through the center, terminating at both ends in the circumference, Fig. 59.

A *radius* of a circle is a straight line joining the center with the

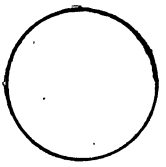


Fig. 58. Circle

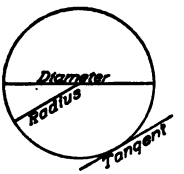


Fig. 59. Diameter, Radius, Tangent

Fig. 60. Quadrant

circumference. All radii of the same circle are equal and their length is always one-half that of the diameter.

An *arc* is any part of the circumference of a circle. An arc equal to one-half the circumference is called a *semi-circumference*, and an arc equal to one-quarter of the circumference is called a *quadrant*, Fig. 60. A quadrant may mean the arc or angle.

A *chord*, Fig. 61, is a straight line which joins the extremities of an arc but does not pass through the center of the circle.

A *secant* is a straight line which intersects the circumference in two points, Fig. 61.

A *segment* of a circle, Fig. 62, is the area included between an arc and a chord.

A *sector* is the area included between an arc and two radii drawn to the extremities of the arc, Fig. 62.

A *tangent* is a straight line which touches the circumference at only one point, called the *point of tangency or contact,* Fig. 59.

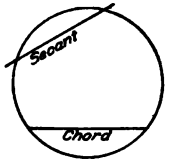


Fig. 61. Chord and Secant

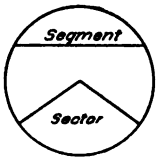


Fig. 62. Segment and Sector

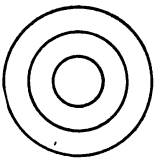


Fig. 63. Concentric Circles

Concentric circles are circles having the same center, Fig. 63.

An *inscribed angle* is an angle whose vertex lies in the circumference and whose sides are chords. It is measured by one-half the intercepted arc, Fig. 64.

A *central angle* is an angle whose vertex is at the center of the circle and whose sides are radii, Fig. 65.

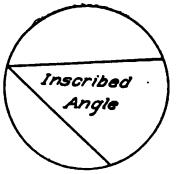


Fig. 64. Inscribed Angle

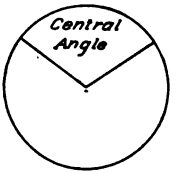


Fig. 65. Central Angle

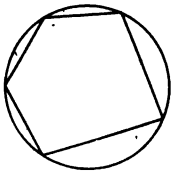


Fig. 66. Inscribed Polygon

An *inscribed polygon* is one whose vertices lie in the circumference and whose sides are chords, Fig. 66.

MEASUREMENT OF ANGLES

To measure an angle, take any convenient radius and describe an arc with the center at the vertex of the angle. The portion of the arc included between the sides of the angle is the *measure of the angle.* If the arc has a constant radius, the greater the divergence of the sides, the longer will be the arc. If there are several arcs drawn with the same center, the intercepted arcs will have different lengths but they will all be the *same fraction* of the entire circumference.

In order that the size of an angle or arc may be stated without saying that it is a certain fraction of a circumference, the circumference is divided into 360 equal parts called *degrees*, Fig. 67. Thus, it may be said that a certain angle contains 45 degrees, *i.e.*, it is $\frac{45}{360}=\frac{1}{8}$ of a circumference. In order to obtain accurate measurements each degree is divided into 60 equal parts called *minutes* and each minute into 60 equal parts called *seconds*.

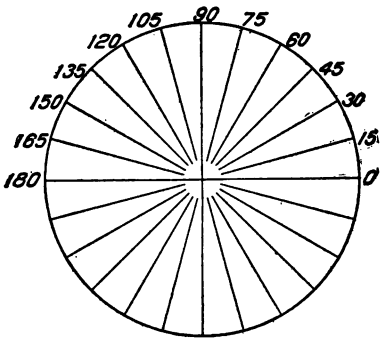


Fig. 67. Angular Measurement

SOLIDS

A *solid* has three dimensions—length, breadth, and thickness. The most common forms of solids are *polyhedrons*, *cylinders*, *cones*, and *spheres*.

POLYHEDRONS

A *polyhedron* is a solid bounded by planes. The bounding planes are called *faces* and their intersections are called *edges*. The intersections of the edges are called *vertices*.

A polyhedron having four faces is called a *tetrahedron;* one having six faces, a *hexahedron;* one having eight faces, and *octahedron*, Fig. 68; one having twelve faces, a *dodecahedron*, etc.

Prisms. A prism is a polyhedron having two opposite faces, called *bases*, which are equal and parallel, and other faces, called

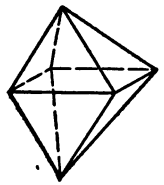


Fig. 68. Octahedron

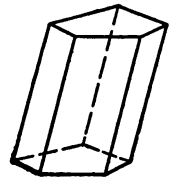


Fig. 69. Prism

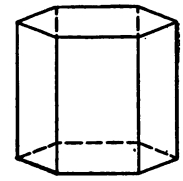


Fig. 70. Right Prism

lateral faces, which are parallelograms, Fig. 69. The *altitude* of a prism is the perpendicular distance between the bases. The area of the lateral faces is called the *lateral area*.

Prisms are called *triangular, rectangular, hexagonal,* etc., according to the shape of the bases. Further classifications are as follows:

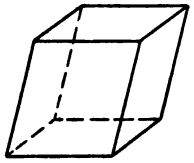


Fig. 71. Parallelopiped

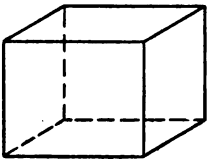


Fig. 72. Rectangular Parallelopiped

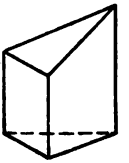


Fig. 73. Truncated Prism

A *right* prism is one whose lateral faces are perpendicular to the bases, Fig. 70.

A *regular* prism is a right prism having regular polygons for bases.

Parallelopiped. A parallelopiped is a prism whose bases are parallelograms, Fig. 71. If all the edges are perpendicular to the bases, it is called a *right parallelopiped.*

A *rectangular parallelopiped* is a right parallelopiped whose bases and lateral faces are rectangles, Fig. 72.

A *cube* is a rectangular parallelopiped all of whose faces are squares.

A *truncated prism* is the portion of a prism included between the base and a plane not parallel to the base, Fig. 73.

Pyramids. A pyramid is a polyhedron whose base is a polygon and whose lateral faces are triangles having a common vertex called the *vertex* of the pyramid.

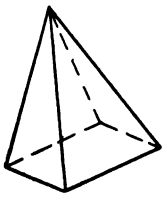


Fig. 74. Pyramid

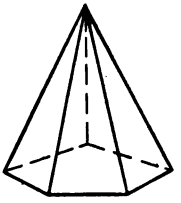


Fig. 75. Regular Pyramid

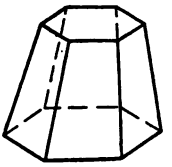


Fig. 76. Frustum of Pyramid

The *altitude* of the pyramid is the perpendicular distance from the vertex to the base.

Pyramids are named according to the kind of polygon forming the base, viz, *triangular, quadriangular,* Fig. 74. *pentagonal,* Fig. 75, *hexagonal.*

A *regular pyramid* is one whose base is a regular polygon and whose vertex lies in a perpendicular erected at the center of the base, Fig. 75.

A *truncated* pyramid is the portion of a pyramid included between the base and a plane not parallel to the base.

A *frustum* of a pyramid is the solid included between the base and a plane parallel to the base, Fig. 76; its *altitude* is the perpendicular distance between the bases.

CYLINDERS

A *cylinder* is a solid having as bases two equal parallel surfaces bounded by curved lines, and as its lateral face the continuous

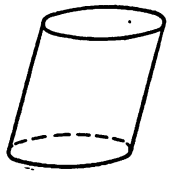


Fig. 77. Cylinder

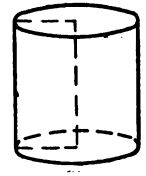


Fig. 78. Right Cylinder

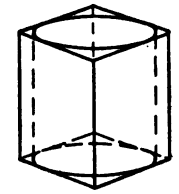


Fig. 79. Inscribed Cylinder

surface generated by a straight line connecting the bases and moving along their circumferences. The bases are usually circles and such a cylinder is called a *circular cylinder*, Fig. 77.

A *right cylinder*, Fig. 78, is one whose side is perpendicular to the bases.

The *altitude* of a cylinder is the perpendicular distance between the bases.

A prism whose base is a regular polygon may be inscribed in or circumscribed about a circular cylinder, Fig. 79.

CONES

A *cone* is a solid bounded by a conical surface and a plane which cuts the conical surface. It may be considered as a pyramid with an infinite number of sides, Fig. 80.

The conical surface is called the *lateral area* and it tapers to a point called the *vertex;* the plane is called the *base.*

The *altitude* of a cone is the perpendicular distance from the vertex to the base.

An *element of a cone* is any straight line from the vertex to the circumference of the base.

A *circular cone* is a cone whose base is a circle.

A *right circular cone,* or *cone of revolution,* Fig. 81, is a cone

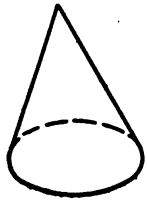


Fig. 80. Cone

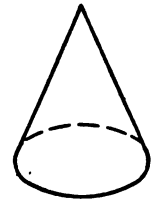


Fig. 81. Right Circular Cone

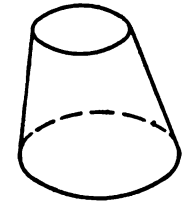


Fig. 82. Frustum of Cone

whose axis is perpendicular to the base. It may be generated by the revolution of a right triangle about one of the legs as an axis.

A *frustum* of a cone, Fig. 82, is the portion of the cone included between the base and a plane parallel to the base; its *altitude* is the perpendicular distance between the bases.

SPHERES

A *sphere* is a solid bounded by a curved surface, every point of which is equally distant from a point within called the *center.*

The *diameter* is a straight line drawn through the center and having its extremities in the curved surface. The *radius*—½ diameter —is the straight line from the center to a point on the surface.

A *plane is tangent to a sphere* when it touches the sphere in only

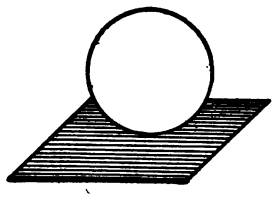


Fig. 83. Plane Tangent to Sphere

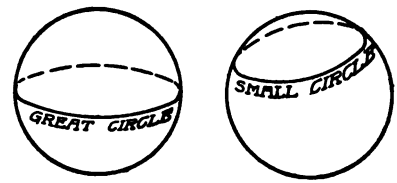


Fig. 84. Great and Small Circle

one point. A plane perpendicular to a radius at its outer extremity is tangent to the sphere, Fig. 83.

An *inscribed polyhedron* is a polyhedron whose vertices lie in the surface of the sphere.

A *circumscribed polyhedron* is a polyhedron whose faces are tangent to a sphere.

A *great circle* is the intersection of the spherical surface and a plane passing through the center of the sphere, Fig. 84.

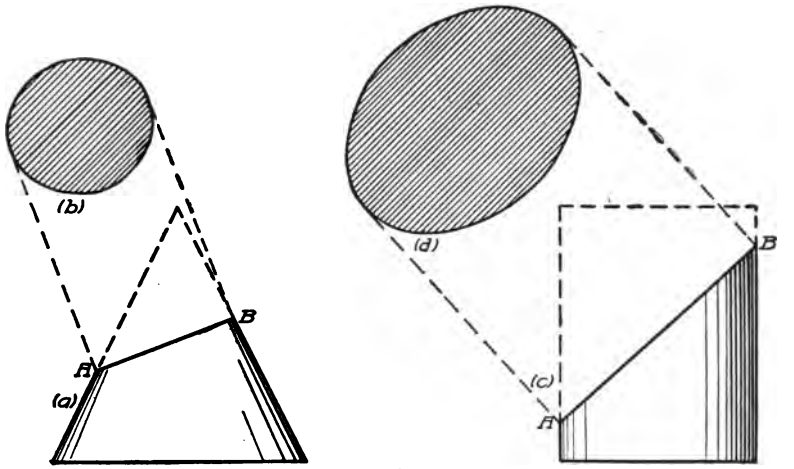


Fig. 85. Intersections of Plane with Cone and Cylinder Giving Ellipses as Shown in (*b*) and (*d*)

A *small circle* is the intersection of the spherical surface and a plane which does not pass through the center, Fig. 84.

CONIC SECTIONS

If a plane intersects a cone at various angles with the base the geometrical figures thus formed are called *conic sections*. A plane perpendicular to the base passing through the vertex of a right circular cone forms an isosceles triangle. If the plane is parallel to the base, the intersection of the plane and the conical surfaces will be the circumference of a circle.

Ellipse. If a plane AB, Fig. 85a, cuts a cone oblique to the axis of the cone, but not cutting the base, the curve formed is called an ellipse, as shown in Fig. 85b, this view being taken perpendicular to the plane AB. If the plane cuts a cylinder as shown in Fig. 85c, the ellipse shown in Fig. 85d is the result, this view being also taken perpendicular to the plane AB. An ellipse may be defined as *a curve generated by a point*

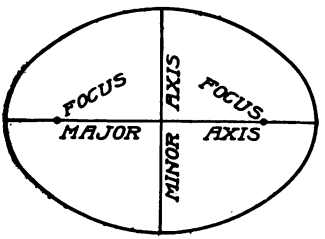


Fig. 86. Diagram Showing Constants of Ellipse

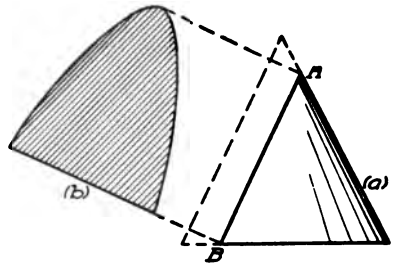


Fig. 87. Intersection of Plane with Cone, Parallel to Element of Cone and Parabolic Section Produced

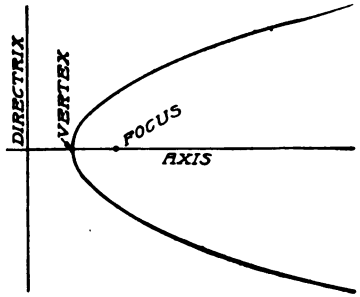


Fig. 88. Diagram Showing Constants of Parabola

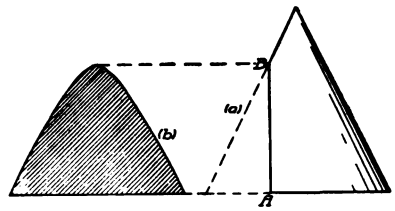


Fig. 89. Intersection of Plane with Cone, Parallel to Axis and Hyperbolic Section Produced

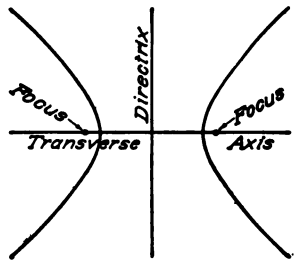


Fig. 90. Diagram Showing Constants of Hyperbola

moving in a plane in such a manner that the sum of the distances from the point to two fixed points shall always be constant.

The two fixed points are called *foci*, Fig. 86, and shall lie on the longest line that can be drawn in the ellipse which is called the *major axis;* the shortest line is called the *minor axis;* and is perpendicular to the major axis at its middle point, called the *center.*

An ellipse may be constructed if the major and minor axes are given or if the foci and one axis are known.

Parabola. If a plane AB, Fig. 87a, cuts a cone parallel to an element of the cone, the curve resulting from this intersection is called a parabola, as shown in Fig. 87b, the view being taken perpendicular to the plane AB. This curve is not a closed curve for the branches approach parallelism.

A parabola may be defined as *a curve every point of which is equally distant from a line and a point.*

The point is called the *focus*, Fig. 88, and the given line, the *directrix.* The line perpendicular to the directrix and passing through the focus is the *axis.* The intersection of the axis and the curve is the *vertex.*

Hyperbola. If a plane AB, Fig. 89a, cuts a cone parallel to its axis, the resulting curve is called a hyperbola,

Fig. 89b, the view being taken perpendicular to the plane AB.

Like the parabola, the curve is not closed, the branches constantly diverging.

A hyperbola is defined as *a plane curve such that the difference between the distances from any point in the curve to two fixed points is equal to a given distance.*

The two fixed points are the *foci* and the line passing through them is the *transverse axis*, Fig. 90.

Rectangular Hyperbola. The form of hyperbola most used in Mechanical Engineering is called the rectangular hyperbola because it is drawn with reference to rectangular coördinates. This curve is constructed as follows: In Fig. 91, OX and OY are the two coördinate axes drawn at right angles to each other. These lines are also called *asymptotes*. Assume A to be a known point on the curve. Draw AC parallel to OX and AD' perpendicular to OX. Mark off any convenient points on AC such as E, F, G, and H, and through these points draw EE', FF', GG', and HH', perpendicular to OX. Connect E, F, G, H, and C with O. Through the points of intersection of the oblique lines and the vertical line AD' draw the horizontal lines LL', MM', NN', PP', and QQ'. The first point on the curve is the assumed point A, the second point is R, the intersection of LL' and EE', the third the intersection S, and so on.

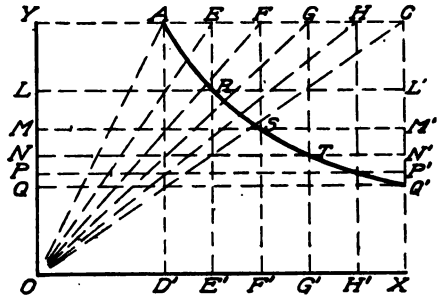


Fig. 91. Construction of Rectangular Hyperbola

In this curve the products of the coördinates of all points are equal. Thus $LR \times RE' = MS \times SF' = NT \times TG'$.

ODONTOIDAL CURVES

Cycloidal Curves. *Cycloid.* The cycloid is a curve generated by a point on the circumference of a circle which rolls on a straight line tangent to the circle, as shown at the left, Fig. 92.

The rolling circle is called the *describing* or *generating circle*, the point on the circle, the *describing* or *generating point*, and the

tangent along which the circle rolls, the *director*. In order that the curve described by the point may be a true cycloid the circle must roll without any slipping.

Hypocycloid. In case the generating circle rolls upon the inside of an arc or circle, the curve thus generated is a hypocycloid,

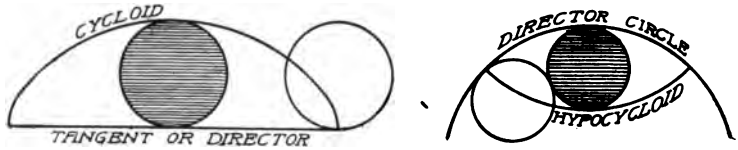


Fig. 92. Geometrical Constructions for Cycloid and Hypocycloid

Fig. 92. If the generating circle has a diameter equal to the radius of the director circle the hypocycloid becomes a straight line.

Epicycloid. If the generating circle rolls upon the *outside* of the *director circle,* the curve generated is an epicycloid, Fig. 93.

Involute Curves. If a thread of fine wire is wound around a cylinder or circle and then unwound, the end will describe an involute curve. The involute may be defined as *a curve generated by a point in a tangent rolling on a circle, known as the base circle,* Fig. 94.

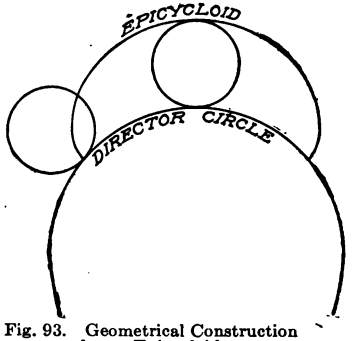


Fig. 93. Geometrical Construction for an Epicycloid

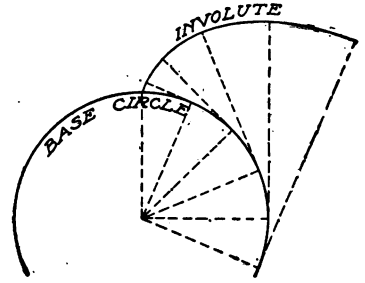


Fig. 94. Geometrical Construction for an Involute

The details of the ellipse, parabola, hyperbola, cycloid, and involute will be taken up in connection with the plates.

The most important application of the cycloidal and involute curves is in the cutting of all forms of gear teeth. It has been found that the teeth of gears when cut accurately to either of these curves will mesh with the least friction and run with exceptional smoothness. The development of these gears and of the machines for cutting them has reached a high state of perfection.

GEOMETRICAL PROBLEMS

The problems given in Plates IV to VIII inclusive have been chosen because of their particular bearing on the work of the mechanical draftsman. They should be solved with great care, as the principles involved will be used in later work.

PLATE IV

Penciling. The horizontal and vertical center lines and the border lines should be laid out in the same manner as in *Plate I.* Now measure off $2\frac{1}{4}$ inches on both sides of the vertical center line and through these points draw vertical lines as shown by the dot and dash lines, *Plate IV.* In locating the figures, place them a little above the center so that there will be room for the number of the problem.

Draw in lightly the lines of each figure with pencil and after the entire plate is completed, ink them. In penciling, all intersections must be formed with great care as the accuracy of the results depends upon it. Keep the pencil points in good order at all times and draw lines *exactly* through intersections.

Problem 1. *To bisect a given straight line.*

Draw the horizontal straight line $A\,C$ about 3 inches long. With the extremity A as a center and any convenient radius—about 2 inches—describe arcs above and below the line $A\,C$. With the other extremity C as a center and with the same radius draw similar arcs intersecting the first arcs at D and E. The radius of these arcs must be greater than one-half the length of the line in order that they may intersect. Now draw the straight line $D\,E$ passing through the intersections D and E. This line will cut $A\,C$ at its middle point F.

Therefore

$$A\,F = F\,C$$

Proof. Since the points D and E are equally distant from A and C a straight line drawn through them is perpendicular to $A\,C$ at its middle point F.

Problem 2. *To construct an angle equal to a given angle.*

Draw the line $O\,C$ about 2 inches long and the line $O\,A$ of about the same length. The angle formed by these lines may be

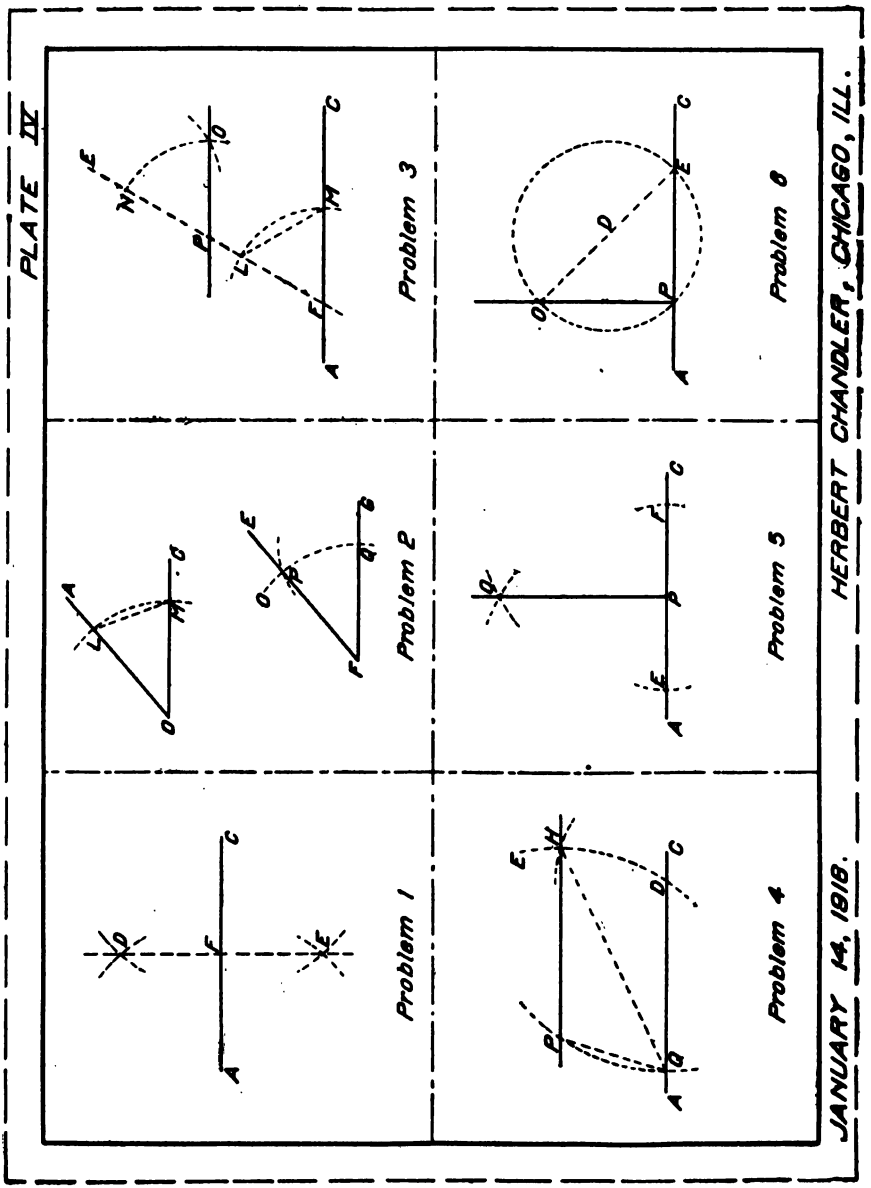


PLATE III
Problem 1
Problem 2
Problem 3
Problem 4
Problem 5
Problem 6
JANUARY 14, 1918.
HERBERT CHANDLER, CHICAGO, ILL.

any convenient size—about 45 degrees is suitable. This angle $A\ O\ C$ is the given angle.

Now draw $F\ G$, a horizontal line about $2\frac{1}{4}$ inches long, and let F, the left-hand extremity, be the vertex of the angle to be constructed.

With O as a center and any convenient radius—about $1\frac{1}{2}$ inches—describe the arc $L\ M$ cutting both $O\ A$ and $O\ C$. With F as a center and the same radius draw the indefinite arc $O\ Q$. Now set the compass so that the distance between the pencil and the needle point is equal to the chord $L\ M$. With Q as a center and a radius equal to $L\ M$ draw an arc cutting the arc $O\ Q$ at P. Through F and P draw the straight line $F\ E$. The angle $E\ F\ G$ is the required angle since it is equal to $A\ O\ C$.

Proof. Since the chords of the arcs $L\ M$ and $P\ Q$ are equal, the arcs are equal. The angles are equal because with equal radii equal arcs are intercepted by equal angles.

Problems 3 and 4. *To draw through a given point a line parallel to a given line.*

First Method. Draw the straight line $A\ C$ about $3\frac{1}{2}$ inches long and assume the point P about $1\frac{1}{2}$ inches above $A\ C$. Through the point P draw an oblique line $F\ E$ forming any convenient angle—about 60 degrees—with $A\ C$. Now construct an angle equal to $P\ F\ C$ having its vertex at P and the line $E\ P$ as one side. (See Problem 2.) The straight line $P\ O$ forming the other side of the angle $E\ P\ O$ will be parallel to $A\ C$.

Proof. If two straight lines are cut by a third making the corresponding angles equal, the lines are parallel.

Second Method. Draw the straight line $A\ C$ about $3\frac{1}{4}$ inches long and assume the point P about $1\frac{1}{2}$ inches above $A\ C$. With P as a center and any convenient radius—about $2\frac{1}{2}$ inches—draw the indefinite arc $E\ D$ cutting the line $A\ C$. Now with the same radius and with D as a center, draw an arc $P\ Q$. Set the compass so that the distance between the needle point and the pencil is equal to the chord $P\ Q$. With D as a center and a radius equal to $P\ Q$, describe an arc cutting the arc $E\ D$ at H. A line drawn through P and H will be parallel to $A\ C$.

Proof. Draw the line $Q\ H$. Since the arcs $P\ Q$ and $H\ D$ are equal and have the same radii, the angles $P\ H\ Q$ and $H\ Q\ D$

are equal. Two lines are parallel if the alternate interior angles are equal.

Problems 5 and 6. *To draw a perpendicular to a line from a point in the line.*

First Method. WHEN THE POINT IS NEAR THE MIDDLE OF THE LINE.

Draw the line $A\,C$ about $3\frac{1}{2}$ inches long and assume the point P near the middle of the line. With P as a center and any convenient radius—about $1\frac{1}{4}$ inches—draw two arcs cutting the line $A\,C$ at E and F. Now with E and F as centers and any convenient radius —about $2\frac{1}{2}$ inches—describe arcs intersecting at O. The line $O\,P$ will be perpendicular to $A\,C$ at P.

Proof. The points P and O are both equally distant from E and F. Hence a line drawn through them is perpendicular to $E\,F$ at P.

Second Method. WHEN THE POINT IS NEAR THE END OF THE LINE.

Draw the line $A\,C$ about $3\frac{1}{2}$ inches long. Assume the given point P to be about $\frac{3}{4}$ inch from the end A. With any point D as a center and a radius equal to $D\,P$, describe an arc cutting $A\,C$ at E. Through E and D draw the diameter $E\,O$. A line from O to P is perpendicular to $A\,C$ at P.

Proof. The angle $O\,P\,E$ is inscribed in a semicircle; hence it is a right angle, and the sides $O\,P$ and $P\,E$ are perpendicular to each other.

Lettering. After completing these figures draw pencil lines for the lettering. Place the words *"Plate IV"* and the date and the name in the border, as in preceding plates. To letter the words "Problem 1," "Problem 2," etc., draw three horizontal lines $\frac{1}{4}$ inch, $\frac{3}{8}$ inch, and $\frac{7}{16}$ inch, respectively, above the horizontal center line and the lower border line to serve as a guide for the size of the letters.

Inking. In inking *Plate IV*, ink in the figures first. Make the line $A\,C$, Problem 1, a full line as it is the given line; make the arcs and the line $D\,E$ dotted as they are construction lines. Similarly in Problem 2, make the sides of the angles full lines and the chord $L\,M$ and the arcs dotted. Follow the same plan in inking the lines of Problems 3, 4, 5, and 6. In Problem 6, ink in only that part of the circumference which passes through the points O, P, and E.

After inking the figures, ink in the heavy border line, and the lettering.

PLATE V

Penciling. In laying out the border lines and center lines follow the directions given for *Plate IV*. Draw the dot and dash lines in the same manner, as there are to be six problems on this plate.

Problem 7. *To draw a perpendicular to a line from a point without the line.*

Draw the straight line $A\ C$ about $3\frac{1}{4}$ inches long, and assume the point P about $1\frac{1}{2}$ inches above the line. With P as a center and any convenient radius—about 2 inches—describe an arc cutting $A\ C$ at E and F. The radius of this arc must always be such that it will cut $A\ C$ in two points; the nearer the points E and F are to A and C, the greater will be the accuracy of the work.

Now with E and F as centers and any convenient radius—about $2\frac{1}{4}$ inches—draw the arcs intersecting below $A\ C$ at T. A line through the points P and T will be perpendicular to $A\ C$. In case there is not room below $A\ C$ to draw the arcs, they may be drawn intersecting above the line as shown at N. Whenever convenient draw the arcs below $A\ C$ for greater accuracy.

Proof. Since P and T are both equally distant from E and F, the line $P\ T$ is perpendicular to $A\ C$.

Problems 8 and 9. *To bisect a given angle.*

First Method. WHEN THE SIDES INTERSECT.

Draw the lines $O\ C$ and $O\ A$—about 3 inches long—forming any angle of 45 to 60 degrees. With O as a center and any convenient radius—about 2 inches—draw an arc intersecting the sides of the angle at E and F. With E and F as centers and a radius of $1\frac{1}{2}$ or $1\frac{3}{4}$ inches, describe short arcs intersecting at I. A line $O\ D$, drawn through the points O and I, bisects the angle.

In solving this problem the arc $E\ F$ should not be too near the vertex if accuracy is desired.

Proof. The central angles $A\ O\ D$ and $D\ O\ C$ are equal because the arc $E\ F$ is bisected by the line $O\ D$. The point I is equally distant from E and F.

Second Method. WHEN THE LINES DO NOT INTERSECT.

Draw the lines $A\ C$ and $E\ F$ about 4 inches long making an

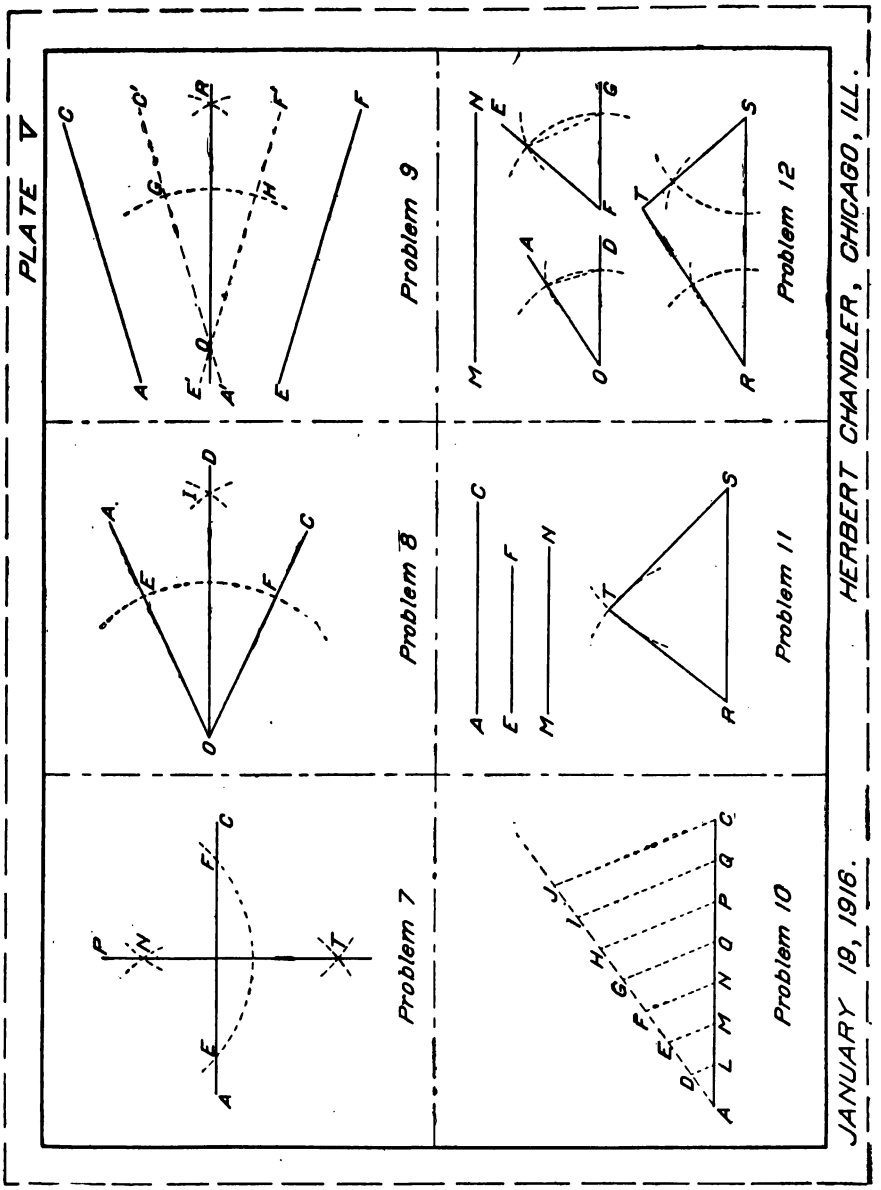


PLATE V
Problem 7
Problem 8
Problem 9
Problem 10
Problem 11
Problem 12
HERBERT CHANDLER, CHICAGO, ILL.
JANUARY 18, 1916.

angle approximately as shown. Draw $A'\ C'$ and $E'\ F'$ parallel to $A\ C$ and $E\ F$ and at such equal distances from them that they will intersect at O. Now bisect the angle $C'\ O\ F'$ by the method given in Problem 8. The line $O\ R$ bisects the given angle.

Proof. Since $A'\ C'$ is parallel to $A\ C$ and $E'\ F'$ is parallel to $E\ F$, the angle $C'\ O\ F'$ is equal to the angle formed by the lines $A\ C$ and $E\ F$. Hence as $O\ R$ bisects angle $C'\ O\ F'$ it also bisects the angle formed by the lines $A\ C$ and $E\ F$.

Problem 10. *To divide a line into any number of equal parts.*

Let $A\ C$—about $3\frac{3}{4}$ inches long—be a given line. Suppose it is desired to divide it into 7 equal parts. First draw the line $A\ J$ at least 4 inches long, forming any convenient angle with $A\ C$. On $A\ J$ lay off, by means of the dividers or scale, points D, E, F, G, etc., each $\frac{1}{2}$ inch apart. (If dividers are used, the spaces need not be exactly $\frac{1}{2}$ inch.) Draw the line $J\ C$ and through the points D, E, F, G, etc., draw lines parallel to $J\ C$. These parallels will divide the line $A\ C$ into 7 equal parts.

Proof. If a series of parallel lines, cutting two straight lines, intercept equal distances on one of these lines, they also intercept equal distances on the other.

Problem 11. *To construct a triangle having given the three sides.*

Draw the three sides, $A\ C$, $2\frac{3}{4}$ inches long; $E\ F$, $1\frac{5}{16}$ inches long; and $M\ N$, $2\frac{8}{16}$ inches long.

Draw $R\ S$ equal in length to $A\ C$. With R as a center and a radius equal to $E\ F$ describe an arc. With S as a center and a radius equal to $M\ N$ draw an arc cutting the arc previously drawn, at T. Connect T with R and S to form the triangle.

Problem 12. *To construct a triangle having given one side and the two adjacent angles.*

Draw the line $M\ N$ $3\frac{1}{4}$ inches long and draw two angles $A\ O\ D$ and $E\ F\ G$ about 30 degrees and 60 degrees respectively.

Draw $R\ S$ equal in length to $M\ N$ and with R as a vertex and $R\ S$ as one side construct an angle equal to $A\ O\ D$. In a similar manner construct at S an angle equal to $E\ F\ G$. Draw lines from R and S through the two established points until they meet at T. The triangle $R\ T\ S$ will be the required triangle.

Lettering. Draw the pencil lines and put in the lettering as in plates already drawn.

Inking. In inking *Plate V*, follow the principles previously used and do not make certain lines dotted until sure that they should be dotted.

After inking the figures, ink in the border lines and the lettering as already explained.

PLATE VI

Penciling. Lay out this plate in the same manner as the preceding plates.

Problem 13. *To describe an arc or circumference through three given points not in the same straight line.*

Locate the three points A, B, and C with a distance between A and B of about 2 inches and a distance between A and C of about $2\frac{1}{4}$ inches. Connect A and B and A and C. Erect perpendiculars to the middle points of $A\,B$ and $A\,C$ as explained in Problem 1. Now draw light pencil lines connecting the intersections I and J and E and F. These lines will intersect at O.

With O as a center and a radius equal to the distance $O\,A$, describe the circumference passing through A, B, and C.

Proof. The point O is equally distant from A, B, and C, since it lies in the perpendiculars to the middle points of $A\,B$ and $A\,C$. Hence the circumference will pass through A, B, and C.

Problem 14. *To inscribe a circle in a given triangle.*

Draw the triangle $L\,M\,N$ of any convenient size. $M\,N$ may be made $3\frac{1}{4}$ inches, $L\,M$, $2\frac{3}{4}$ inches, and $L\,N$, $3\frac{1}{2}$ inches. Bisect the angles $M\,L\,N$ and $L\,M\,N$ by the method used in Problem 8. The bisectors $M\,I$ and $L\,J$ intersect at O, which is the center of the inscribed circle. The radius of the circle is equal to the perpendicular distance from O to one of the sides.

Proof. The point of intersection of the bisectors of the angles of a triangle is equally distant from the sides.

Problem 15. *To inscribe a regular pentagon in a given circle.*

With O as a center and a radius of about $1\frac{1}{2}$ inches, describe the given circle. With the T-square and triangles draw the center lines $A\,C$ and $E\,F$ perpendicular to each other and passing through O. Bisect one of the *radii*, $O\,C$, at H and with this point as a center and a radius $H\,E$, describe the arc $E\,P$. This arc cuts the diameter $A\,C$ at P. With E as a center and a radius $E\,P$, draw arcs cutting

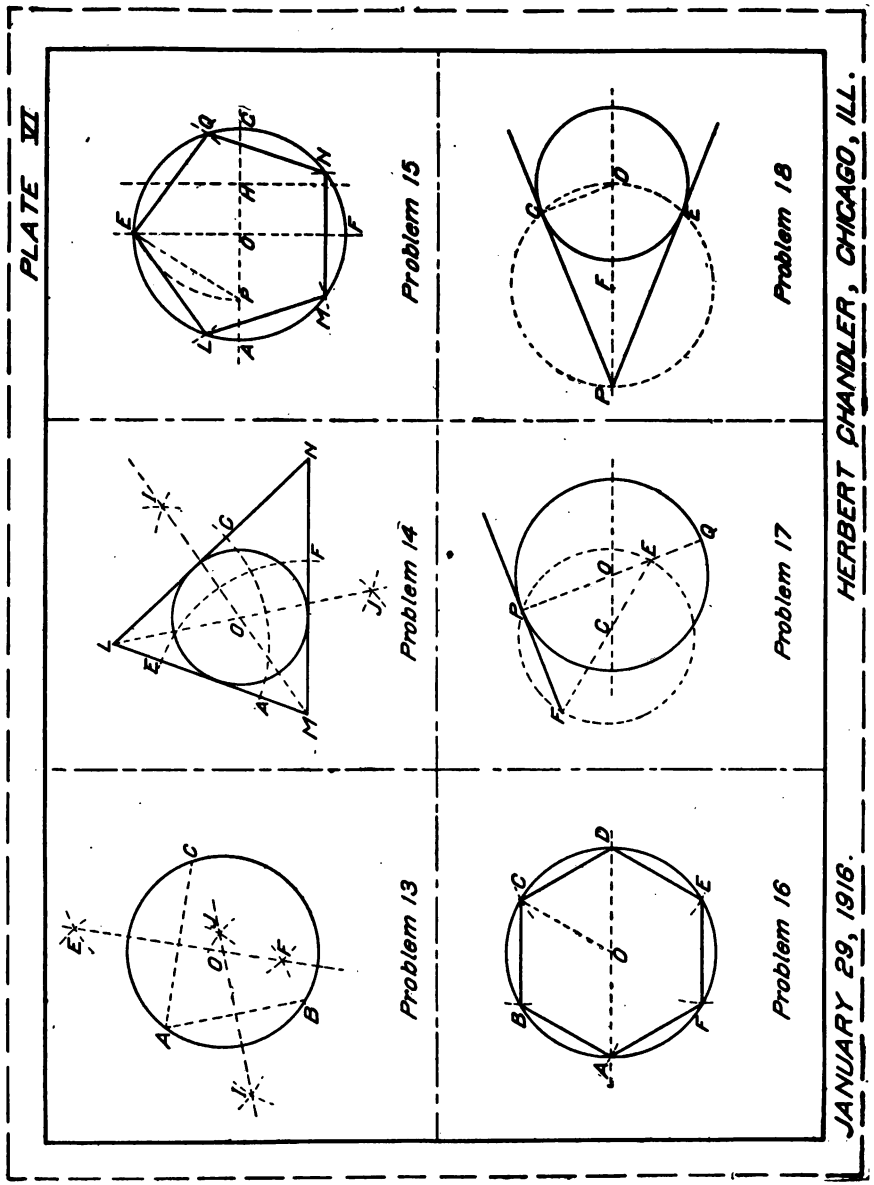


PLATE III
Problem 15
Problem 18
Problem 14
Problem 17
Problem 13
Problem 16
JANUARY 29, 1916.
HERBERT CHANDLER, CHICAGO, ILL.

the circumference at L and Q. With the same radius and centers at L and Q, draw the arcs cutting the circumference at M and N.

The pentagon is completed by drawing the chords $E\,L$, $L\,M$, $M\,N$, $N\,Q$, and $Q\,E$.

Problem 16. *To inscribe a regular hexagon in a given circle.*

With O as a center and a radius of $1\frac{3}{8}$ inches draw the given circle. With the T-square draw the diameter $A\,D$. With D as a center, and a radius equal to $O\,D$, describe arcs cutting the circumference at C and E. Now with C and E as centers and the same radius, draw the arcs, cutting the circumference at B and F. Draw the hexagon by joining the points thus formed.

Therefore, in order to inscribe a regular hexagon in a circle, mark off chords equal in length to the radius.

To inscribe an equilateral triangle in a circle the same method may be used, the triangle being formed by joining the opposite vertices of the hexagon.

Proof. Since the triangle $O\,C\,D$ is an equilateral triangle by construction, the angle $C\,O\,D$ is one-third of two right angles and one-sixth of four right angles. Hence arc $C\,D$ is one-sixth of the circumference and the chord is a side of a regular hexagon.

Problem 17. *To draw a line tangent to a circle at a given point on the circumference.*

With O as a center and a radius of about $1\frac{1}{4}$ inches draw the given circle. Assume some point P on the circumference and join the point P with the center O. By the method given in Problem 6, *Plate IV*, construct a perpendicular to $P\,O$, which perpendicular will be the desired tangent to the circle at the point P.

Proof. A line perpendicular to a radius at its extremity is tangent to the circle.

Problem 18. *To draw a line tangent to a circle from a point outside the circle.*

With O as a center and a radius of about 1 inch draw the given circle. Assume P some point outside of the circle about $2\frac{1}{2}$ inches from the center. Draw a straight line passing through P and O. Bisect $P\,O$ and with the middle point F as a center describe the circle passing through P and O. Draw a line from P through the intersection of the two circumferences C. The line $P\,C$ is tangent to the given circle. Similarly $P\,E$ is tangent to the circle.

Proof. The angle $P\ C\ O$ is inscribed in a semicircle and hence is a right angle. Since $P\ C\ O$ is a right angle, $P\ C$ is perpendicular to $C\ O$. The perpendicular to a radius at its extremity is tangent to the circumference.

Inking. In inking *Plate VI*, the same method should be followed as in previous plates.

PLATE VII

Penciling. Lay out this plate in the same manner as the preceding plates.

Problems 19 and 20. *To draw an ellipse when the axes are given.*

First Method. Draw the lines $L\ M$ and $C\ D$ about $3\frac{1}{4}$ and $2\frac{1}{4}$ inches long respectively, making $C\ D$ perpendicular to $L\ M$ at its middle point P and having $C\ P = P\ D$. The two lines, $L\ M$ and $C\ D$, are the axes. With C as a center and a radius $L\ P$ equal to one-half the major axis, draw the arc, cutting the major axis at E and F. These two points are the foci.

Now locate several points on $P\ M$, such as A, B, and G. With E as a center and a radius equal to $L\ A$, draw arcs above and below $L\ M$. With F as a center and a radius equal to $A\ M$ describe short arcs cutting those already drawn as shown at N. With E as a center and a radius equal to $L\ B$ draw arcs above and below $L\ M$ as before. With F as a center and a radius equal to $B\ M$, draw arcs intersecting those already drawn as shown at O. The point R and others are found by repeating the process. The student is advised to find at least 12 points on the curve—6 above and 6 below $L\ M$. These 12 points with L, C, M, and D will enable him to draw the curve.

After locating these points, draw a free-hand curve passing through them.

Second Method. Draw the two axes $A\ B$ and $P\ Q$ in the same manner as in the first method. With O as a center and a radius equal to one-half the major axis, describe a circle. Similarly with the same center and a radius equal to one-half the minor axis, describe another circle. Draw any radii such as $O\ C$, $O\ D$, $O\ E$, $O\ F$, etc., cutting both circumferences. These radii may be drawn with the 60 and 45 degree triangles. From C, D, E, and F, the points of intersection of the radii with the large circle, draw *vertical* lines and from C', D', E', and F', the points of intersection of the radii with

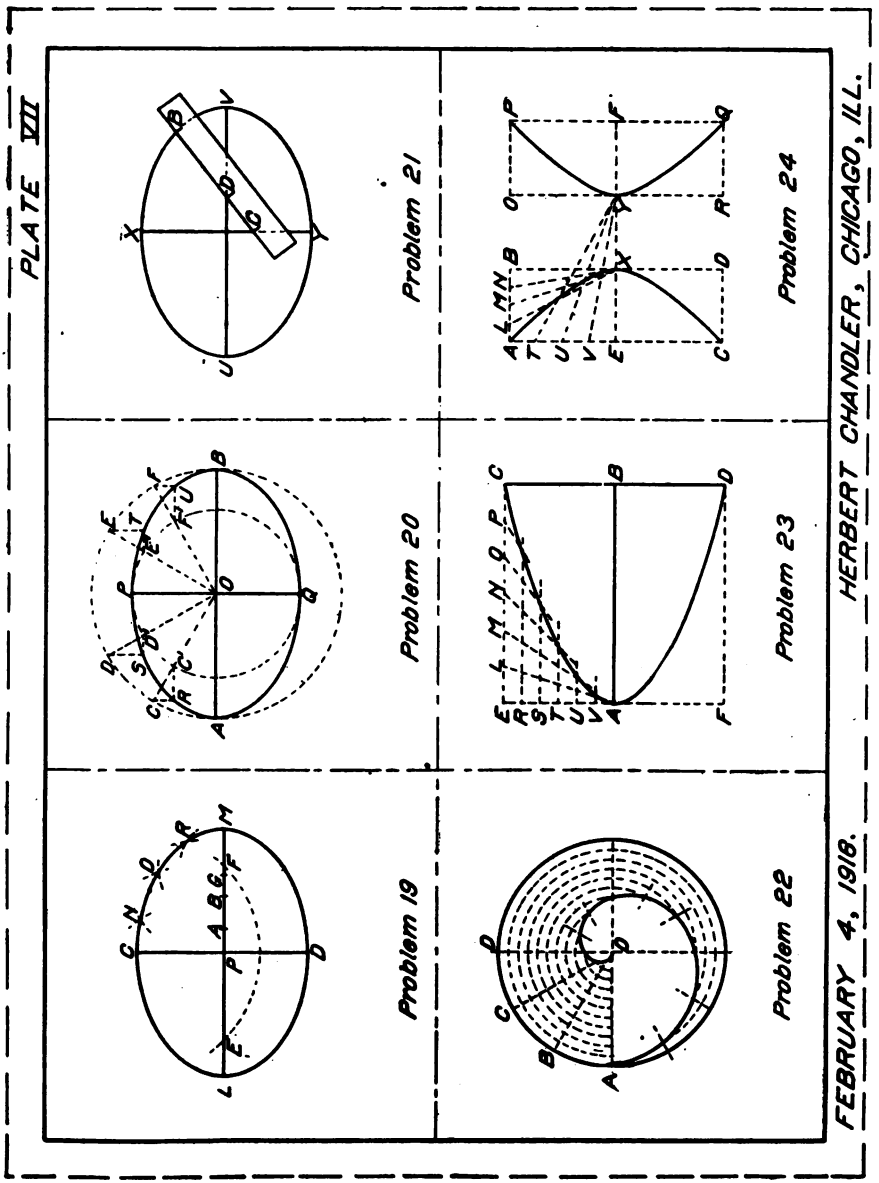


PLATE VIII
Problem 21
Problem 24
Problem 20
Problem 23
Problem 19
Problem 22
FEBRUARY 4, 1918.
HERBERT CHANDLER, CHICAGO, ILL.

the small circle, draw *horizontal* lines The intersections of these lines are points on the ellipse.

Draw a free-hand curve* passing through these points; about five points in each quadrant will be sufficient.

Problem 21. *To draw an ellipse by means of a trammel.*

As in Problems 19 and 20, draw the major and minor axes, $U\ V$ and $X\ Y$. Take a slip of paper having a straight edge and mark off $C\ B$ equal to one-half the major axis, and $D\ B$ equal to one-half the minor axis. Place the slip of paper in various positions keeping the point D on the major axis and the point C on the minor axis. If this is done, the point B will mark various points on the curve. Find as many points as necessary and sketch the ellipse.

Problem 22. *To draw a spiral of one turn in a circle.*

Draw a circle with the center at O and a radius of $1\frac{1}{2}$ inches. Locate twelve points, $\frac{1}{8}$ inch apart on the radius $O\ A$ and draw circles through these points. With the 30-degree triangle, draw radii OB, OC, OD, etc., 30 degrees apart, thus forming 12 equal parts.

The points on the spiral are now located; the first is at the center O; the next is at the intersection of the line $O\ B$ and the first circle; the third is at the intersection of $O\ C$ and the second circle; the other points are located in the same way. Sketch in pencil a smooth curve passing through these points.

Problem 23. *To draw a parabola when the abscissa and ordinate are given.*

Draw the straight line $A\ B$—about three inches long—as the axis, or *abscissa* of the parabola. At A and B draw the lines $E\ F$ and $C\ D$ perpendicular to $A\ B$, and with the T-square draw $E\ C$ and $F\ D$, $1\frac{1}{2}$ inches above and below $A\ B$, respectively. Let A be the vertex of the parabola. Divide $A\ E$ and $E\ C$ into the same number of equal parts. Through R, S, T, U, and V, draw horizontal lines and connect L, M, N, O, and P, with A. The intersections of the horizontal lines with the oblique lines are points on the curve. For instance, the intersection of $A\ L$ and the line V is one point and the intersection of $A\ M$ and the line U is another.

The lower part of the curve $A\ D$ is drawn in a similar manner.

Problem 24. *To draw a hyperbola when the abscissa $E\ X$, the ordinate $A\ E$, and the diameter $X\ Y$ are given.*

*See Page 16, Mechanical Drawing, Part I.

Draw *E F* about 3 inches long and mark the point *X*, 1 inch from *E* and the point *Y*, 1 inch from *X*. With the triangle and T-square, draw the rectangles *A B D C* and *O P Q R* such that *A B* is 1 inch in length and *A C*, 3 inches in length. Divide *A E* and *A B* into the same number of equal parts. Connect *Y* with the points *T*, *U*, and *V*, on *A E*, and connect *X* with *L*, *M*, and *N*, on *A B*. The first point on the curve is at *A*; the next is at the intersection of *T Y* and *L X*; the third is at the intersection of *U Y* and *M X*. The remaining points are found in the same manner. Repeat the process for *X C* and the right-hand curve *P Y Q*.

Inking. In inking the figures on this plate, use the French or irregular curve and make full lines for the curves and their axes. Dot the construction lines as usual. Ink in all the construction lines used in finding one-half of a curve, and in Problems 19, 20, 23, and 24 leave all construction lines in *pencil* except those inked. In Problems 21 and 22 erase all construction lines not inked. The trammel used in Problem 21 may be drawn in the position shown, or outside of the ellipse in any convenient place.

The same lettering should be done on this plate as on previous plates

PLATE VIII

Penciling. In laying out *Plate VIII*, draw the border lines and horizontal and vertical center lines as in previous plates, dividing the plate into four spaces.

Problem 25. *To construct a cycloid when the diameter of the generating circle is given.*

With *O'* as a center and a radius of $\frac{7}{8}$ inch draw a circle, and, tangent to it, draw the indefinite horizontal straight line *A B*. Divide the circle into any number of equal parts—12 for instance—and through these points of division *C*, *D*, *E*, *F*, etc., draw horizontal lines. Now with the dividers set so that the distance between the points is equal to the chord of the arc *C D*, mark off the points *L*, *M*, *N*, *O*, *P*, on the line *A B*, commencing at the point *H*. At these points erect perpendiculars to the center line *X O'* which is the line of centers of the generating circle as it rolls along the line *A B*. With the intersections *Q*, *R*, *S*, *T*, etc., as centers describe arcs of circles as shown. The points on the cycloid will be the intersections of

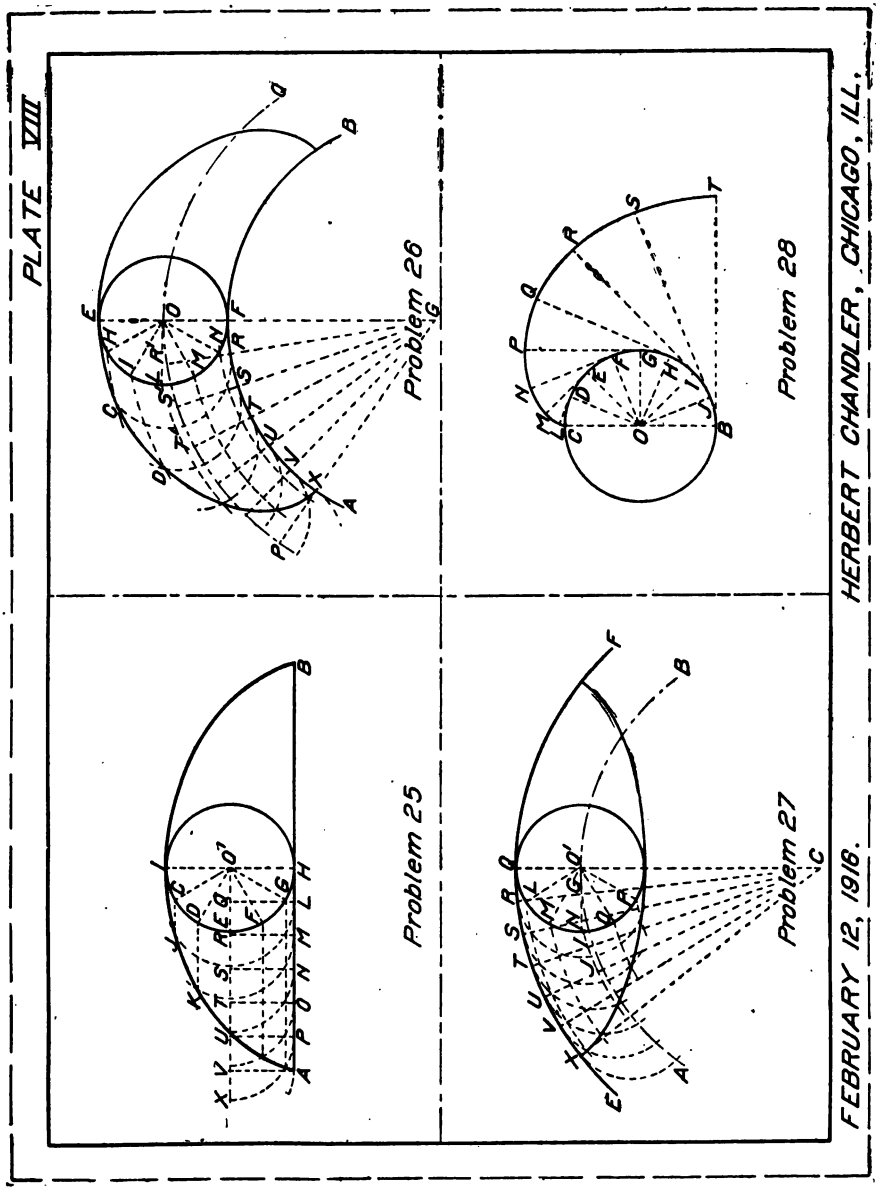


PLATE VIII
Problem 26
Problem 28
Problem 25
Problem 27
FEBRUARY 12, 1918.
HERBERT CHANDLER, CHICAGO, ILL.

these arcs and the horizontal lines drawn through the points C, D, E, F, etc. Thus the intersection of the arc whose center is Q and the horizontal line through C is a point J on the curve. Similarly, the intersection of the arc whose center is R and the horizontal line through D is the point K on the curve. The remaining points on the left, as well as those on the right, are found in the same manner. To obtain great accuracy in this curve, the circle should be divided into a large number of equal parts, because the greater the number of divisions the less the error due to the difference in length between a chord and its arc.

Problem 26. *To construct an epicycloid when the diameter of the generating circle and the diameter of the director circle are given.*

The epicycloid and the hypocycloid may be drawn in the same manner as the cycloid if arcs of circles are used in place of the horizontal lines. With O as a center and a radius of $\frac{3}{4}$ inch describe a circle. Draw the diameter $E\,F$ of this circle and produce $E\,F$ to G such that the line $F\,G$ is $2\frac{3}{4}$ inches long. With G as a center and a radius $F\,G$, describe the arc $A\,B$ of the director circle. With the same center G, draw the arc $P\,Q$ which will be the path of the center of the generating circle as it rolls along the arc $A\,B$. Now divide the generating circle into any number of equal parts—twelve for instance—and through the points of division H, I, L, M, and N, draw arcs having G as a center. With the dividers set so that the distance between the points is equal to the chord $H\,I$, mark off distances on the director circle $A\,F\,B$. Through these points of division R, S, T, U, etc., draw radii intersecting the arc $P\,Q$ in the points R', S', T', etc., and with these points as centers describe arcs of circles as in Problem 25. The intersections of these arcs with the arcs already drawn through the points H, I, L, M, etc., are points on the epicycloid. Thus the intersection of the circle whose center is R' with the arc drawn through the point H is a point upon the curve. Also the arc whose center is S' with the arc drawn through the point I is another point on the curve. The remaining points are found by repeating this process.

Problem 27. *To draw an hypocycloid when the diameter of the generating circle and the radius of the director circle are given.*

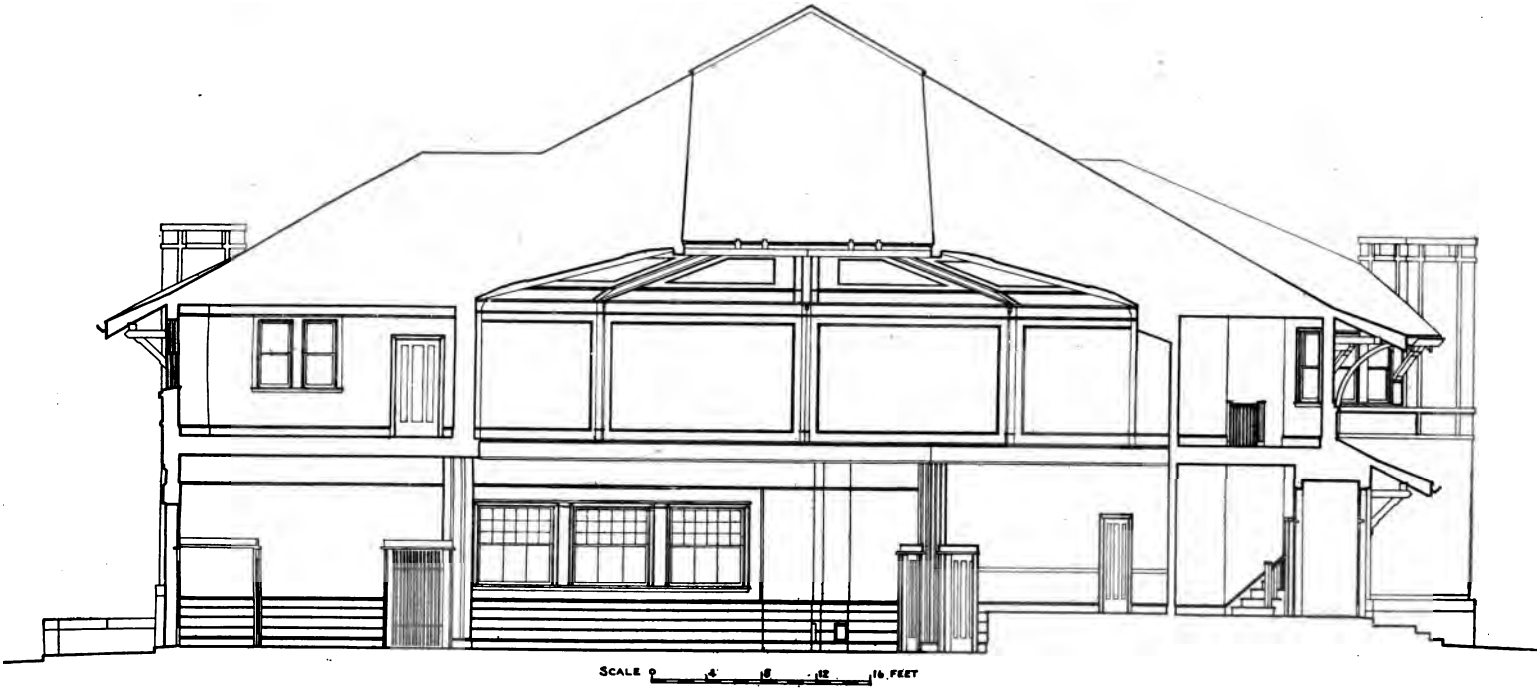
With C as a center and a radius of 4 inches describe the arc $E\,F$, which is the arc of the director circle. Now with the same

center and a radius of $3\frac{1}{4}$ inches, describe the arc $A\ B$, which is the line of centers of the generating circle as it rolls on the director circle. With O' as a center and a radius of $\frac{3}{4}$ inch describe the generating circle. As before, divide the generating circle into any number of equal parts—12, for instance—and with these points of division L, M, N, O, etc., draw arcs having C as a center. Upon the arc $E\ F$, lay off distances $Q\ R$, $R\ S$, $S\ T$, etc., equal to the chord $Q\ L$. Draw radii from the points R, S, T, etc., to the center of the director circle C and describe arcs of circles having a radius equal to the radius of the generating circle, using the points G, I, J, etc., as centers. As in Problem 26, the intersections of the arcs are the points on the hypocycloid. By repeating this process, the right-hand portion of the curve may be drawn.

Problem 28. *To draw the involute of a circle when the diameter of the base circle is known.*

With the point O as a center and a radius of 1 inch, describe the base circle. Divide the circle into any number of equal parts—16, for instance—and draw radii to the points of division. At the point D, draw a light pencil line perpendicular to $O\ D$. This line will be tangent to the circle. Similarly at the points E, F, G, H, etc., draw tangents to the circle. Set the dividers so that the distance between the points will be equal to the chord of the arc $C\ D$, and measure this distance from D along the tangent. From the point E, measure on the tangent a distance equal to two of these chords; from the point F, three divisions; and from the point G, four divisions. Similarly, measure distances on the remaining tangents, each time adding the length of the chord. This will give the points L, M, N, P, etc., to T. The curve drawn through these points will be the involute of the circle.

Inking. Observe the same rules in inking *Plate VIII* as were given for *Plate VII*. In Problems 25 and 26 the arcs and lines used in locating the points of the other half of the curve may be left in pencil. In Problem 28, all construction lines should be inked. After completing the problems the same lettering should be done on this plate as on previous plates.



LONGITUDINAL SECTION

LONGITUDINAL SECTION THROUGH MUSIC BUILDING FOR DOANE COLLEGE, CRETE, NEBRASKA
Dean and Dean, Architects, Chicago, Illinois

For floor plans see opposite page 109. For exterior see page 67.

MECHANICAL DRAWING

PART III

PROJECTIONS

ORTHOGRAPHIC PROJECTION

Definitions. *Projection.* The word projection means *to throw forward.* In mechanical drawing, the significance is *to throw forward in straight lines.* Projection really means, therefore, either the act or the result of projecting parallel rays from the surface of a body and of cutting these rays with a plane, so as to obtain on the

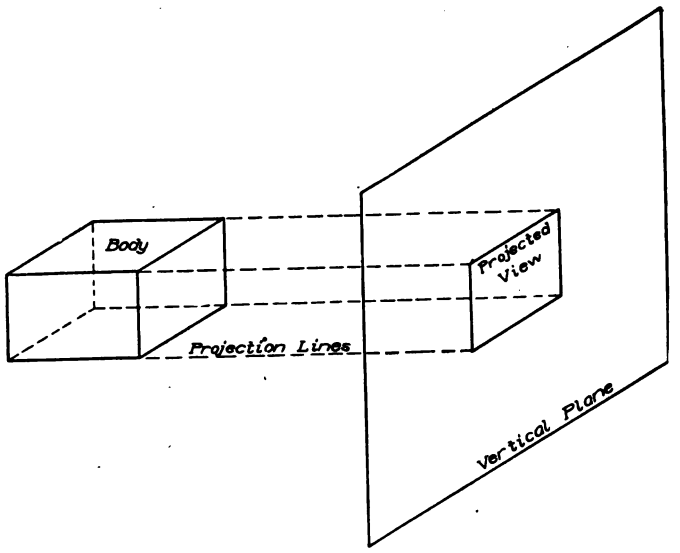


Fig. 95. Body and Its Projection

plane a shape corresponding point for point with that of the body. The rays are called *projecting lines.* A plane may be considered transparent, since it is a flat surface having no thickness.

View. In Fig. 95 a body is shown as projecting from its surface projection lines, and these lines are cut by a plane. By connecting the points on the plane made by the projection lines the

projection of the body is formed, and it corresponds in shape with the body itself. A projection of this kind is called a *view*, this name being given it on account of the fact that an observer on the same side of the body as the projection plane would get this view.

It can readily be seen that one view only will not give a complete picture of a solid object. Usually two or more views are necessary, according to the complication of the object or body. When two or three views are shown, they are pictured on two or three planes at right angles to each other. In this way views of two or three sides are shown, and this is usually sufficient to give the idea of the complete form of the object.

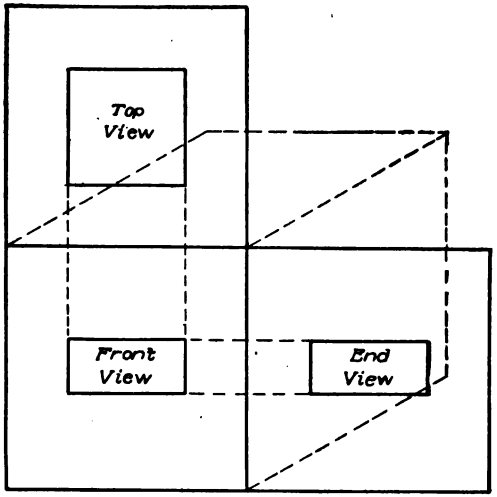


Fig. 96. Projections of Top, Front, and End of Body

Orthographic. The word *orthographic* means at right angles, and in mechanical drawing, in connection with the word projection, it means that two or more views are projected on planes at right angles with each other. The various views of a body have special names—those showing vertical faces are called *elevations*, such as front, side, end or rear elevation; a view of the top of a body is called a *plan* or *plan view;* and a view of the under side, a *bottom view.*

Third-Angle Projection. In Fig. 96 is shown three faces of a body projected on three planes—the top view on the top plane, the front view on the front plane, and the end view on the end plane. It will be seen that the same body is represented as projecting rays in three directions, and thus the three projections, or views, are obtained. It will also be seen that the three planes with their views have been brought into one plane, that is, the surface of the paper. This brings the top view directly above the front view, and the end view to the right of the front view. The above is a definition of

true projection, usually called *third-angle projection,* and is the method used by practically all draftsmen in this country.

First-Angle Projection. There is, however, a method called first-angle projection, used but little now in this country, although formerly in almost general use. Because draftsmen may have to do at times with old drawings or drawings made in foreign countries, it is well for them to understand first-angle projection. This method

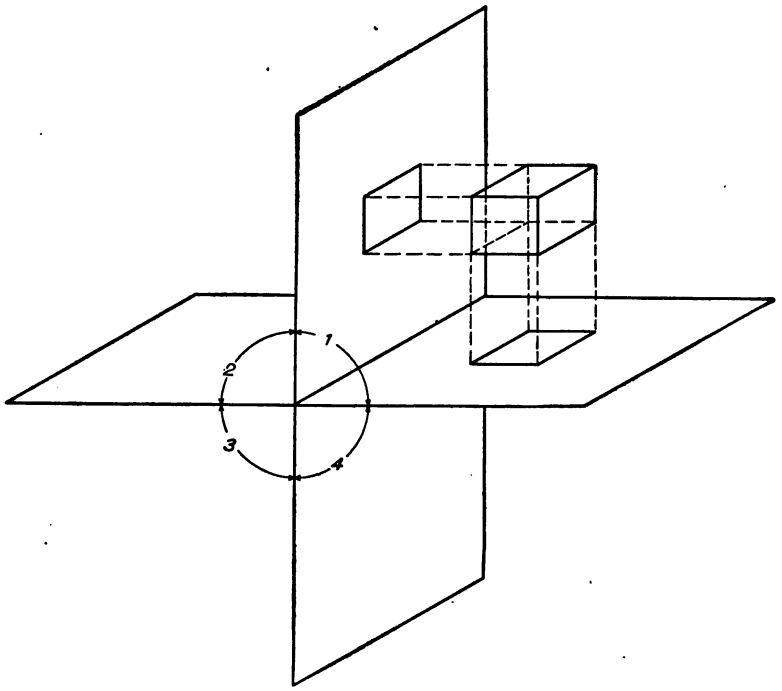


Fig. 97. Body and Its First-Angle Projections

brings the front view, or elevation, above the top view, or plan, the end view being at the right of the front view. Fig. 97 shows this method of first-angle projection.

Comparison of Third- and First-Angle Projection. Perhaps a short explanation will make clear the meaning of third- and first-angle projection. In geometry, when two planes intersect at right angles, the angles are designated as first, second, third, and fourth, as numbered in Fig. 97. In first-angle projection, the body is placed in angle 1, and a top view is projected on a plane under the body.

This passes the projection lines back through the body, instead of throwing them out from the surface. In fact, by this method, the body is supposed to turn itself inside out, an absurdity which led to the general abandonment of the method in this country. Third-angle projection places a body in angle 3, and projects a top view on to the plane above it, and a front view on to the plane in front of it. This is true projection.

Projection Methods. When a drawing is made by projection, an object is represented just as it would be seen if one eye were closed and the other were directly over each point of the object at the same time. As an illustration of this, place a box on a table and a piece of ground glass a few inches in front of it. Now, stand

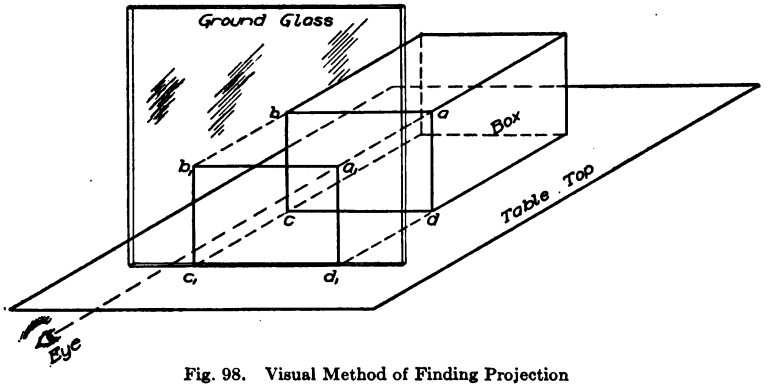


Fig. 98. Visual Method of Finding Projection

so that one eye will come directly in line with one corner *a*, Fig. 98. Make a dot at a_1 where the line from the eye to the corner *a* passes through the glass. Next, move the eye until it is directly in line with the corner *b* of the box, and put a dot at b_1 where the line from the eye to the corner *b* passes through the glass. Repeat this process, putting dots on the glass at c_1 and d_1 where the lines from the eye to the corners *c* and *d* pass through the glass. Now, connect the points a_1, b_1, c_1, and d_1, and the complete projection of the front of the box will be shown by the figure on the glass. This

NOTE. The first four figures in this textbook, Figs. 95, 96, 97, and 98, are pictorial views given to show the student clearly how the views of objects are projected. The student in drawing orthographic projections does not need to draw the pictorial views, but simply the projections, as illustrated in Figs. 99 to 129, inclusive.

figure is a rectangle, and is the same shape and size as the front of the box.

It is readily seen that from this one projection drawing, or view, no idea of the depth of the box is given, although the width and height are correctly shown. A top, or plan, view must now be made to show the depth of the box. Place another piece of ground glass a few inches above the box and, with the eye directly over each separate corner of the top, repeat the process of making the four dots, representing each top corner. Connect these four dots, and the figure thus formed represents the top projection, or plan view, of the box. Now, arrange the two pieces of glass, as shown in Fig. 99. The box being removed, the upper glass is simply lowered to the table, and the front glass is turned from the bottom forward and up, and laid directly below the upper glass.

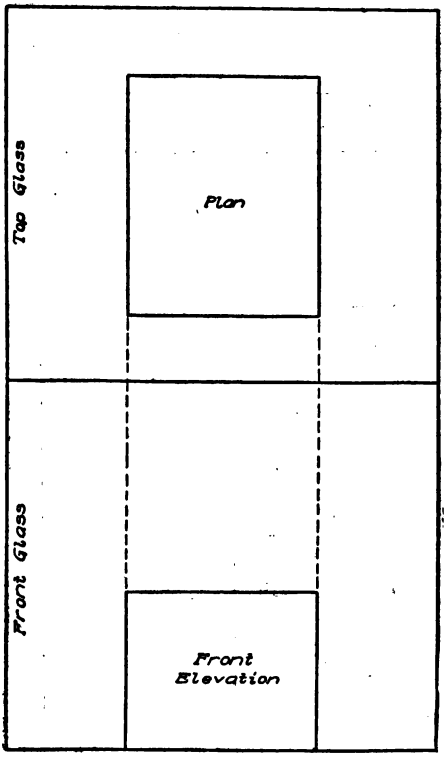


Fig. 99. Plan and Elevation of Box Shown in Fig. 98

This position of the figures represents the two projections—front elevation and plan—just as they would be drawn by a draftsman on a sheet of drawing paper. The width of the box is shown in both views, and being the same in each, the front elevation and plan are both of equal width, and therefore each point in the plan is directly over the corresponding point in the front elevation. In more complicated objects, where the complete idea cannot be obtained from the front elevation and plan views, an end view or both end views must be shown as in Fig. 100, which represents the projections of a box with a curved top. These end views are obtained by taking two or more

pieces of ground glass, placing them one in front of each end, and then drawing the projections. This is done, as in the cases of the

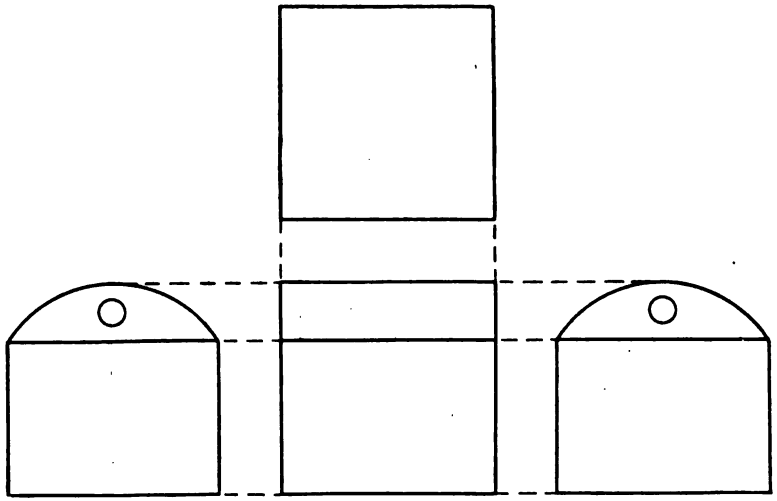


Fig. 100. Plan, Elevation, and End Views of a Box with a Curved Top

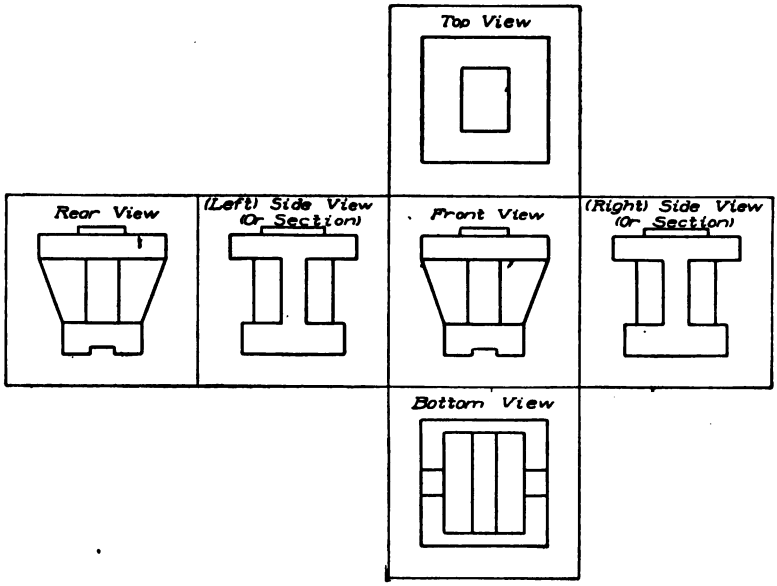


Fig. 101. Six Views of Object
Courtesy of Pennsylvania Railroad Company, Altoona, Pennsylvania

front elevation and plan, by making several dots for the shape of the top, and drawing a curved line through these dots. The two

end views are placed as shown—the right-hand view at the right of the front view, and the left-hand view at the left. This gives the proper arrangement of the views as a draftsman would work them out on paper.

In Fig. 101 is represented a practical case where the object is sufficiently complicated to require a view of each of its six faces. As will be seen in the figure, six views are shown—front, top,

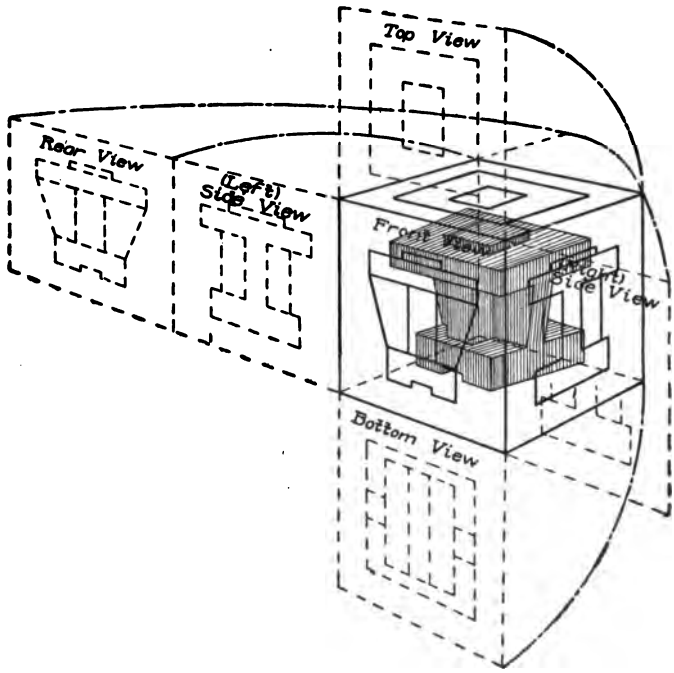


Fig. 102. Folding Out of the Projection Planes Into the Plane of the Surface of the Drawing Paper
Courtesy of Pennsylvania Railroad Company, Altoona, Pennsylvania

bottom, right side, left side, and rear. In Fig. 102 is represented the method of folding out the projection planes after the faces of the object have been projected on them, in order to have them all in one plane—that of the surface of the drawing paper, as shown in Fig. 101.

Drawing the Projection on Paper. From the explanation just given, it will be seen that the projection views are all of the same size as the faces of the object they represent. They can, therefore,

be drawn just as readily on a sheet of drawing paper without the use of the ground glass. For the front view, measure the four front edges of the object, and lay off on the paper a figure of the same shape as the front of the object. Repeat the process for the top of the object, obtaining the top view, or plan; and for each end of the object, obtaining the end view, or side views. The bottom and rear views can be placed in the same way. Draw the plan view with its four corners directly over the four corners of the front view, and the bottom view with its four corners directly under. Draw the right end, or side, view with its four corners directly to the right of the four corners of the front elevation, and the left end, or left side, view and rear view, with their corners directly to the left of the corners of the front view.

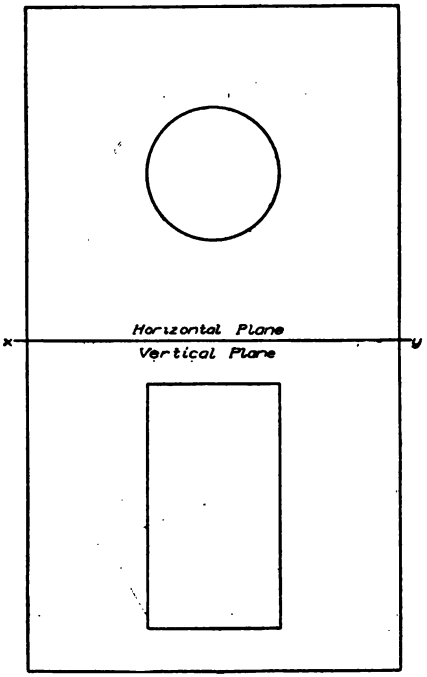


Fig. 103. Ground Line, *xy*, at Intersection of Horizontal and Vertical Planes

Projection Lines. As each projected point of an object shown in plan view must be directly over the projection of the same point in the front elevation, a vertical dotted line will connect these points, as projected in pairs; and as each projected point in an end view must be directly opposite the projection of the same point in the front elevation, a horizontal dotted line will connect these points, as projected in pairs. These dotted lines are called projection or construction lines.

Ground Line. Having the two planes, at right angles, on which the front elevation and plan are represented, when the top plane is turned up to bring the plan above the front elevation, as represented on the surface of the drawing paper, it revolves on the intersecting line of the two planes as an axis. This intersecting line *xy*

in Fig. 103, is called the ground line, and this is usually abbreviated to *GL*. The projections may be placed at any convenient distance above or below the *GL*, unless these distances are given in any problem. In beginning all ordinary projection work, it is customary to show the *GL* as a horizontal line between the front elevation and plan views, and the projection of any pair of points in the front and plan views are always in a line perpendicular to the *GL*. This is evident from the fact that the points in the plan view are directly

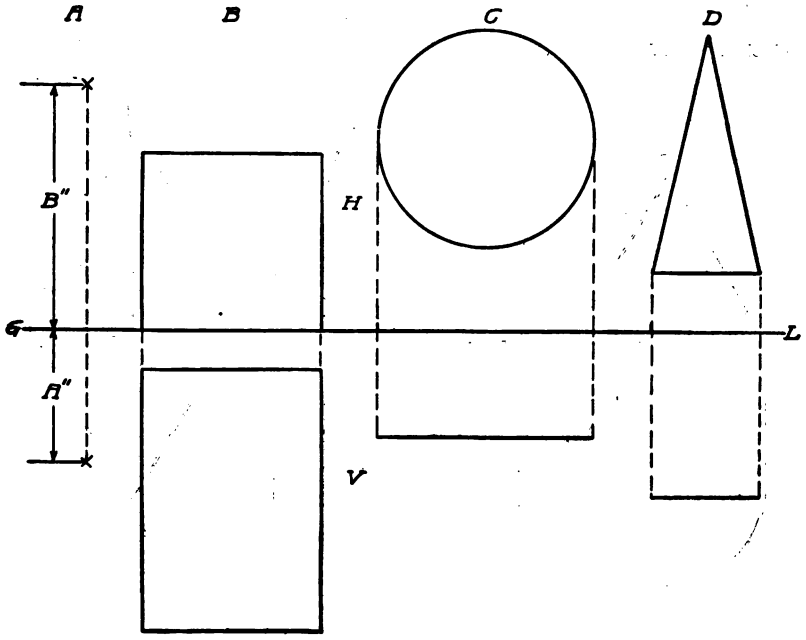


Fig. 104. Typical Projections

over the corresponding points in the front elevation. Although the ground line is usually used in learning the subject of projections, it is customary to omit it in practical work.

Rules of Projection. (1) *If a surface is perpendicular to either plane of projection, its projection on that plane is simply a line—a straight line if the surface is plane, a curved line if the surface is curved.*

(2) *The projected view of any point of any object on a plane is in a perpendicular drawn to the plane through the point of the object.*

(3) *If a straight line is perpendicular to a plane, its projection on that plane is a point; and if the straight line is parallel to the plane, the projection is a line equal in length to the line itself and makes the same angle with the ground line.*

(4) *All points on any object at the same height above its base must appear in the front elevation at the same distance below the ground line, and all points on an object at the same distance back of the front face must appear in the plan at the same distance above the ground line.*

Typical Examples of Projection. Figs. 104 and 105 show clearly several ideas of plan and elevation. In such work as this, it is

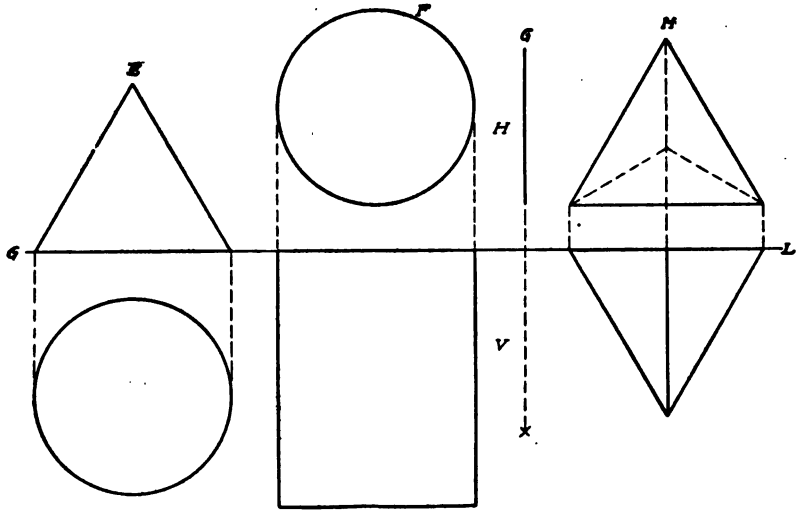


Fig. 105. Typical Projections

customary to call the vertical plane on which the front elevation is drawn V, and the horizontal plane on which the plan is drawn H.

A = a point A'' below H, and B'' in front of V

B = a square prism resting against V, two of its faces parallel to H

C = a circular disk in space parallel to H

D = a triangular card in space parallel to H

E = a cone with its base resting against V

F = a cylinder perpendicular to H, and with one end resting against H

G = a line perpendicular to V

H = a triangular pyramid back of V, with its base resting against H

PRACTICAL PROBLEMS IN PROJECTION

1. *Square Bar.* Fig. 106 represents a square bar. A is the front elevation, and shows the length and width of the bar, but not the thickness. There must then be another view. B is the plan,

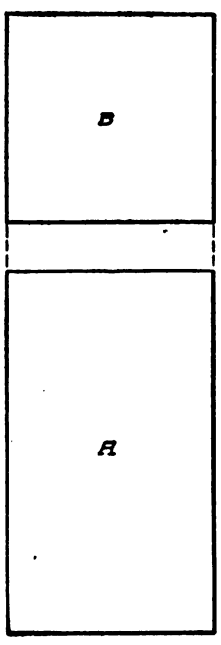


Fig. 106. Projections of Square Bar

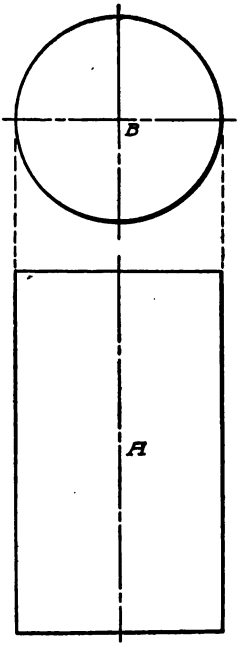


Fig. 107. Projections of Round Bar

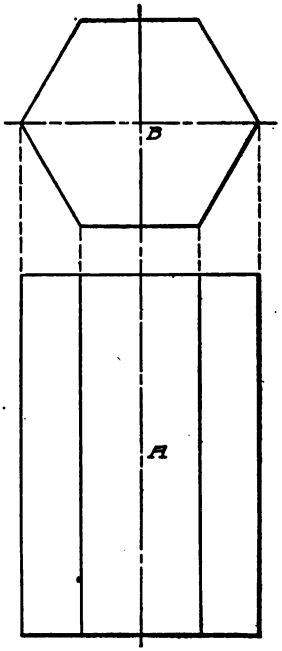


Fig. 108. Projections of Hexagonal Bar

and shows the width and thickness of the bar. From these two views the complete form of the bar is obtained and no other views are necessary when such is the case. In all working drawings, only as many views are shown as is necessary to determine the complete form of the object being drawn.

2. *Round Bar.* Fig. 107 represents a round bar. The front elevation A, shows the width and height of the bar, but does not show that it is round. The plan B, shows the circular top of the bar and of the proper diameter. In this problem, in addition to the

dotted projection lines connecting points in plan and elevation, it is advisable to put in dot and dash lines for center lines. Projection lines and center lines are construction lines, and may be erased when the drawing is finished, unless otherwise ordered.

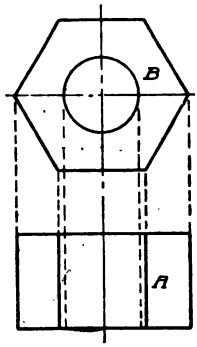


Fig. 109. Projections of Hexagonal Nut

3. *Hexagonal Bar.* Fig. 108 represents a hexagonal bar. In this case, center lines should be drawn. The front elevation *A*, shows the length of the bar, and the plan *B*, shows the form and the distance between faces. The vertical lines in the front elevation show the corners of the hexagonal form while both views show the distance from corner to corner of the hexagonal top.

4. *Hexagonal Nut.* Fig. 109 represents a hexagonal nut. Center lines should be drawn here also. The front elevation *A*, shows the thickness and width of the nut, and the circular hole is shown by heavy dotted lines. Holes are always represented in this way. The plan *B*, shows the shape of the top of the nut, and also the shape of the hole.

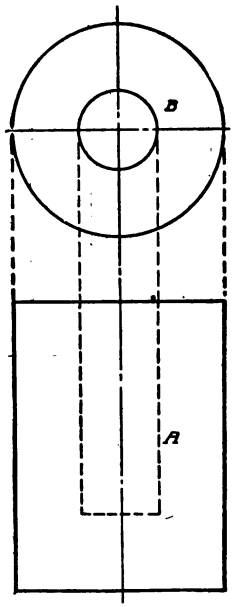


Fig. 110. Projections of Cylinder with Circular Hole

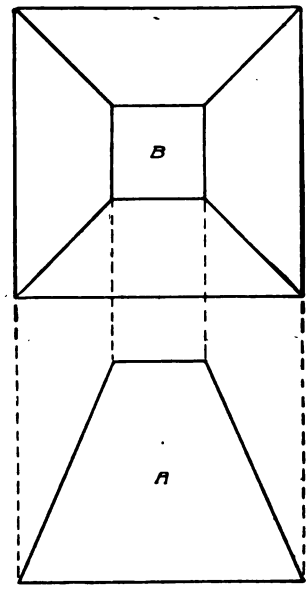


Fig. 111. Projections of Frustum of Square Pyramid

5. *Cylinder with Circular Hole.* Fig. 110 represents a cylinder with a circular hole passing part way through. Center lines are needed here, and in fact where any circle, hexagon, octagon, or other shape except a square or rectangle occurs. The front elevation *A*, shows the height and width of the cylinder, and the depth and width of hole. The plan *B*, shows the top of the cylinder, its diameter, and the diameter of the hole.

6. *Frustum of Square Pyramid.* Fig. 111 represents a block in the form of a frustum of a square pyramid. The front elevation *A*, shows the height of the block, and the width of the top and bottom faces. The plan *B*, shows the width and depth of the top and bottom faces, and also the edges connecting these faces of the frustum.

7. *Square Bar with Cylindrical Portion.* Fig: 112 represents a square bar with a portion forged to a cylindrical form. The front elevation *A*, shows the length and width of the bar, and also the length and width of the cylindrical portion. The plan *B*, shows the square top, and by the dotted circle shows the shape of the cylindrical portion. The fact that this circle is dotted means that the cylindrical portion does not come clear through to the top. A bottom view *C*, is also shown here, as it gives a better idea of the complete form of the bar. Enough views should always be shown by the draftsman to give the workman a clear idea of what he is to make.

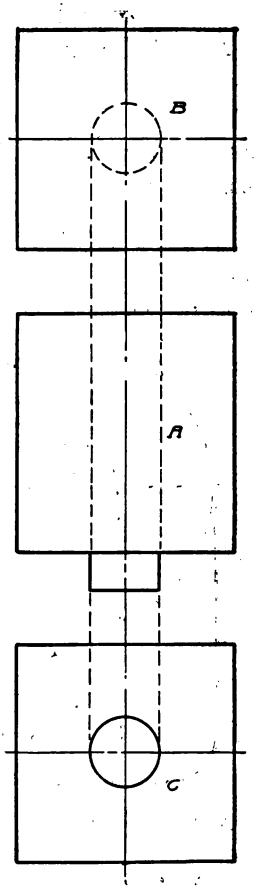


Fig. 112. Projections of Square Bar with Cylindrical Portion

8. *Circular Ring Made from Round Rod.* Fig. 113 represents a circular ring made from a round rod. The front elevation *A*, shows the thickness and the diameter of the ring, and the plan *B*, shows the circular form.

9. *Block with Number of Different Dimensions.* Fig. 114 represents a block with a number of different dimensions. The block

has been turned down in such a way that there are five different diameters, as shown. All these diameters, and the lengths between, may be shown in the front elevation *A*. From this view, only the forms of the cross-section could not be ascertained. Some might be square, some hexagonal, or some circular, but the plan *B* shows that all are circular.

Summary. The principles of projection which have been used so far, may be stated as follows:

(1) If a line is parallel to either the vertical or horizontal plane, its actual length is shown on that plane, and its other projection is parallel to the ground line.

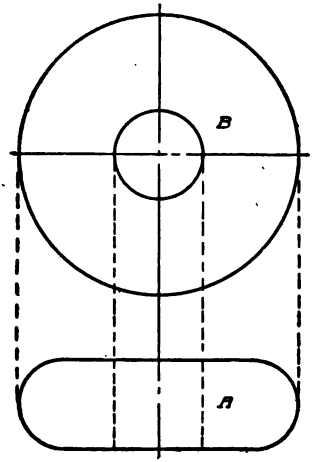


Fig. 113. Projections of Circular Ring

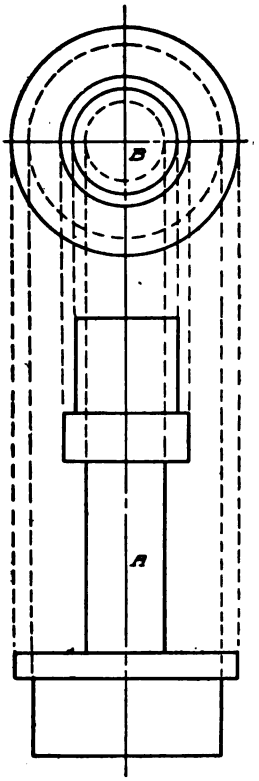


Fig. 114. Projections of Turned Block

(2) A line oblique to either plane has its projections on that plane shorter than the line itself, and its other projection oblique to the ground line.

(3) No projection can be longer than the line itself.

(4) If two lines intersect, their projections must cross, and the point of crossing in the front elevation must be directly under the point of crossing in the plan.

(5) A plane surface, if parallel to either plane, is shown on that plane in its true size and shape; if oblique, it is shown smaller than the true size, and if perpendicular it is shown as a straight line.

(6) Lines parallel in space have both their vertical and horizontal projections parallel.

TRUE LENGTH OF LINES

Principles. If a line is parallel to a plane, its projection on that plane will be equal in length to the line itself, as represented in Fig. 115. If a line is perpendicular to a plane, its projection on

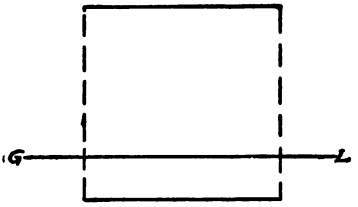


Fig. 115. Projections of a Line Parallel to Plane

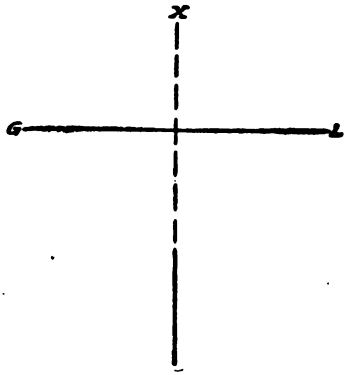


Fig. 116. Projections of a Line Perpendicular to Plane

the plane will be a point, as represented by the cross in Fig. 116. If a line is inclined to a plane, its projection on that plane will be shorter than the line itself, as represented in Fig. 117. If a line is parallel to the horizontal or vertical plane, its projection on the other plane will be parallel to the ground line, as represented in Fig. 118. A line inclined to both the horizontal

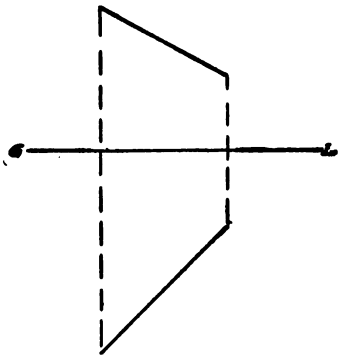


Fig. 117. Projections of a Line Inclined to Plane

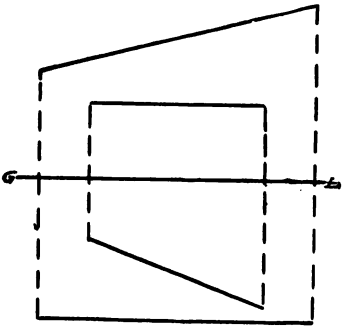


Fig. 118. Projections of Lines Parallel to Ground Line

and vertical planes will not show its true length in either projection, as represented in Fig. 119. In a case like the one last mentioned, the true length of the line is found by revolving the line until it is parallel to one of the planes. Then, its projection on that plane will be its true length.

True Length by Revolving Horizontal Projection. In Fig. 120 is shown the horizontal and vertical projections of the line AB, and to find the true length of the line itself proceed as follows: Swing the horizontal projection $A^h B^h$ about one end A^h as a pivot, until it is parallel to the ground line. Project the new point $B_1{}^h$ downward to a point on the vertical plane to a line drawn from B^v parallel to the ground line, locating the point $B_1{}^v$. The line connecting $B_1{}^v$ and A^v is the true length desired, since the true length of a line is always shown by its projection on a plane when the line is parallel to that plane.

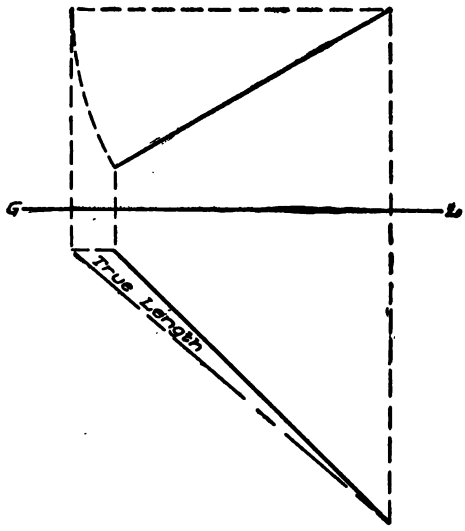


Fig. 119. True Length of Inclined Line not Shown in Its Projections

True Length by Revolving Vertical Projection. In Fig. 121 is shown the method of finding the true length of the same line as

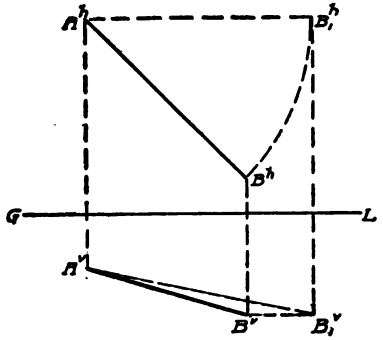


Fig. 120. True Length of a Line by Revolving Horizontal Projection

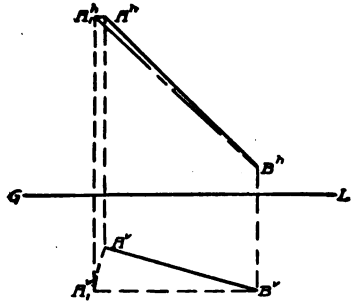


Fig. 121. True Length of a Line by Revolving Vertical Projection

in Fig. 120, but by revolving the vertical projection. The method is the same. Revolve $A^v B^v$ about the end B^v as a pivot until it is parallel to the ground line, and then project $A_1{}^v$ up to $A_1{}^h$ on the

horizontal plane at the same distance from the ground line as A^h. The true length is then shown on the horizontal plane by the line connecting $A_1{}^h$ and B^h. Projection lines representing the true length are always shown as dot and dash lines, as in Fig. 120 and 121.

REPRESENTATION OF OBJECTS

Rectangular Prism or Block. In Fig. 122 there is represented a rectangular prism or block, whose length is twice its width. The elevation shows its height. As the block is placed at an angle, three of the vertical edges will be visible, and the fourth, invisible. In mechanical drawing, the edges, which in projection form a part of the outline or contour of the figure, must always be visible, hence are always drawn as full lines, while the lines or edges which are invisible are drawn dotted. The plan shows what lines are visible in elevation, and the elevation determines what are visible in plan. In Fig. 122, the plan shows that the dotted edge AB is the back edge, and in Fig. 123, the elevation shows that the dotted edge CD is the lower edge of the triangular prism. In general, if in elevation an edge projected *within* the figure is a back edge, it must be dotted, and in plan, if an edge projected within the outline is a lower edge, it is dotted.

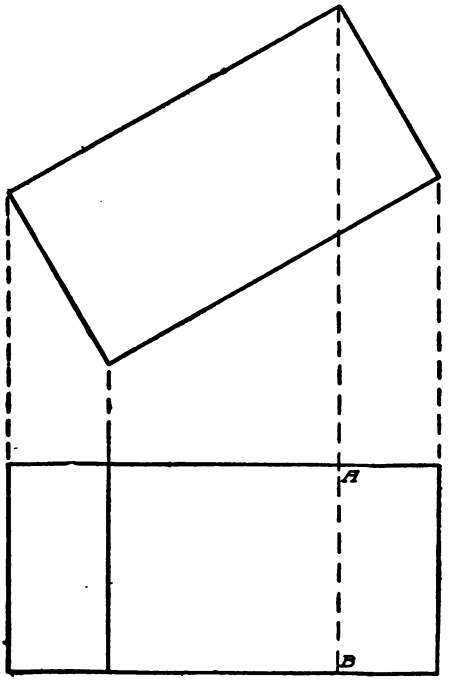


Fig. 122. Projections of a Rectangular Prism or Block

Triangular Prism or Block. The end view shown in Fig. 123 is obtained by projecting the points of the plan across to a plane at right angles to the horizontal and vertical planes, then revolving them down through 90 degrees and continuing the projections to meet the projection lines drawn across from

the elevation. Connecting the points thus obtained gives the end view. End or side views of any object are obtained by projection in this way.

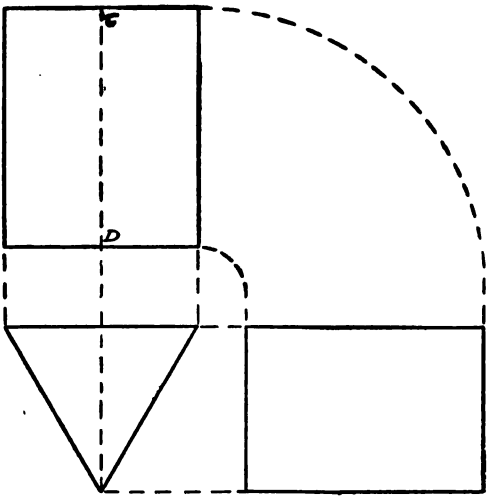


Fig. 123. Projections of a Triangular Prism or Block

Triangular Block with Square Hole. The plan, elevation, and end views of a triangular block with a square hole from end to end are shown in Fig. 124. In this case the plan and elevation alone would not be sufficient to positively determine the shape of the hole, but the end view shows at a glance that it is square.

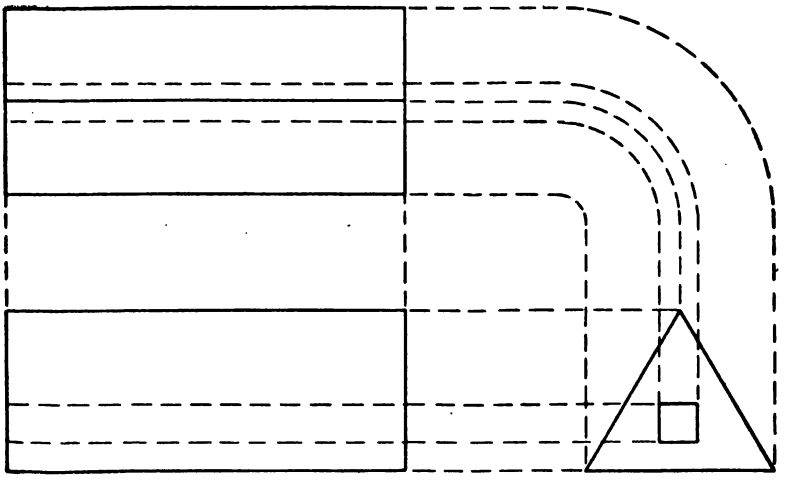


Fig. 124. Projections of a Triangular Block with Square Hole

ROTATING AND INCLINING OF OBJECTS

Method of Rotating Object. The natural way to place an object to be shown by projections would be in the simplest position; that is, with an edge or face parallel to either the horizontal or

vertical plane of projection. Sometimes it is necessary, however, to draw the views of an object in a position at an angle to the planes. In such case it is usually advisable to draw the object parallel to one of the planes, and then rotate it to the required position about an axis perpendicular to a plane of projection.

When an object is rotated in this way, about an axis perpendicular to a plane, its projection on that plane will remain unchanged

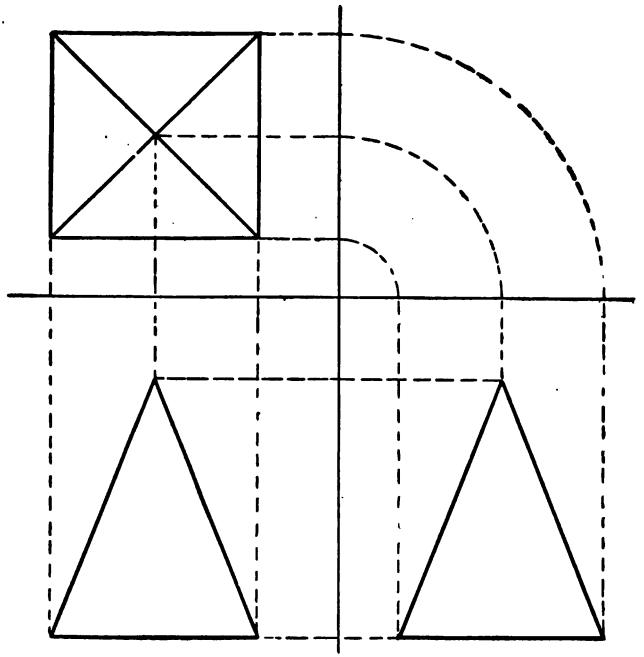


Fig. 125. Plan, Front, and Side Views of a Square Pyramid

in size and shape, and the dimensions parallel to this axis on the other planes will remain the same.

Pyramid. In Fig. 125, the plan, front, and side views of a pyramid are shown, and in Fig. 126 is shown the same pyramid after it has been rotated through 30 degrees about an axis perpendicular to the horizontal plane. The height of the pyramid has not been altered by this rotation and, therefore, the front and side views are the same height as in the original front view.

Now, if the pyramid in Fig. 125 is rotated about an axis perpendicular to the vertical plane, the front view will not be altered,

and may be copied in the new position at an angle of 30 degrees, as shown in Fig. 127. The distances above the ground line to any points in the top view are not altered, and the distances of the various points can be taken on the lines projected up from the points of the front view with a pair of dividers, or the points can be obtained by projecting across from the original top view to meet the projection lines drawn up from the front view. The side view dimensions are not altered, and this view can therefore be obtained in

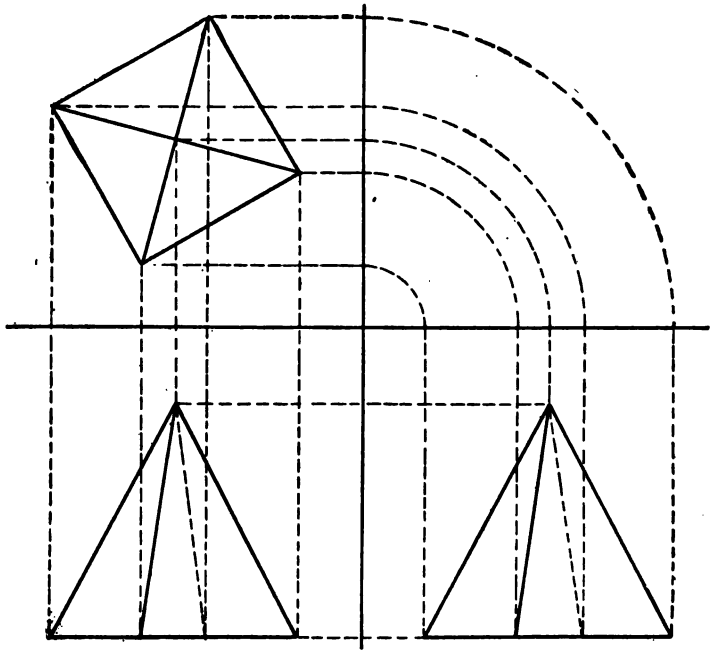


Fig. 126. Plan, Front and Side Views after Revolving Pyramid in Fig. 125 through 30 Degrees with Vertical Plane

the usual way, by projecting across from the front view, and revolving down from the plane at right angles to the horizontal and vertical planes the points projected across from the top view.

Cylinder in Inclined Position to Horizontal Plane. As shown in Fig. 128, first draw the plan, a circle, at *A*. Then draw the rectangle at *B*, representing the front view. Now, draw the rectangle at *C*, representing the front view at the desired angle. This rectangle *C* is the same size as the view at *B*, since the cylinder

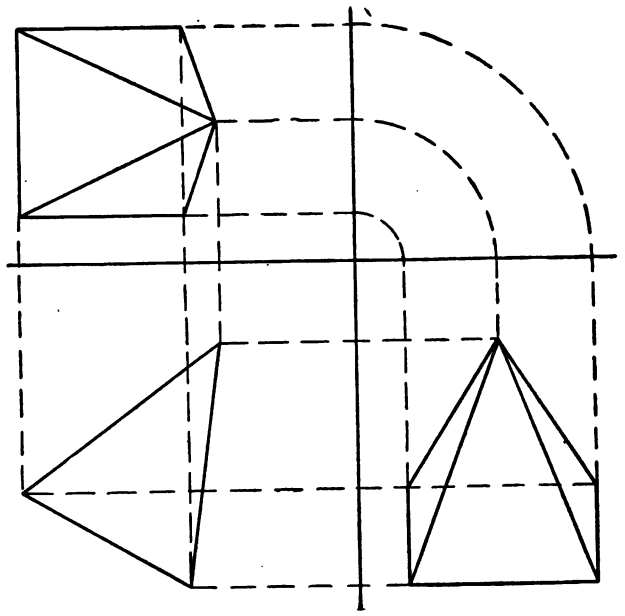


Fig. 127. Plan, Front, and Side Views after Revolving Pyramid in Fig. 125 through 30 Degrees with Horizontal Plane

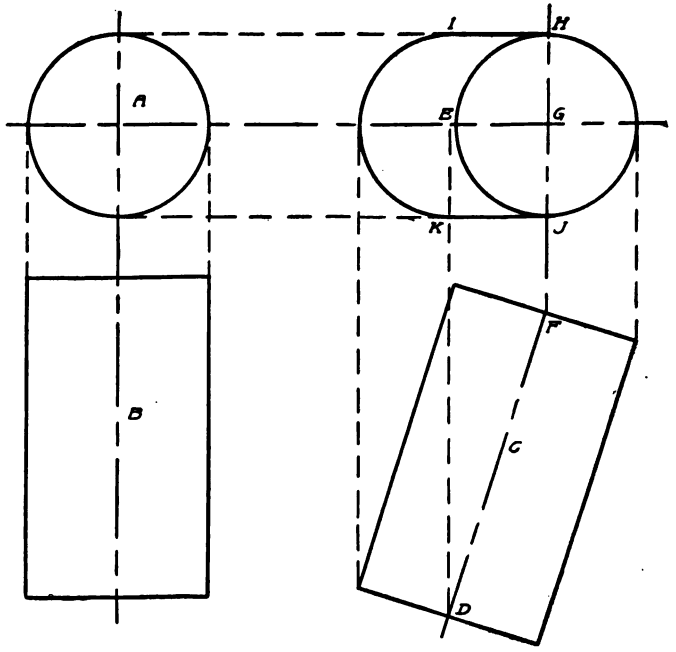


Fig. 128. Projections of Cylinder Inclined to Horizontal Plane

has simply been inclined to the horizontal plane, but kept parallel to the vertical plane. The point D, the center of the circle forming the base of the cylinder, is projected up to the point E, and with this point as a center, a circle representing the plan view of the base is drawn. Then from F project up to G, and with this point as a center draw the circle representing the plan view of the top of the

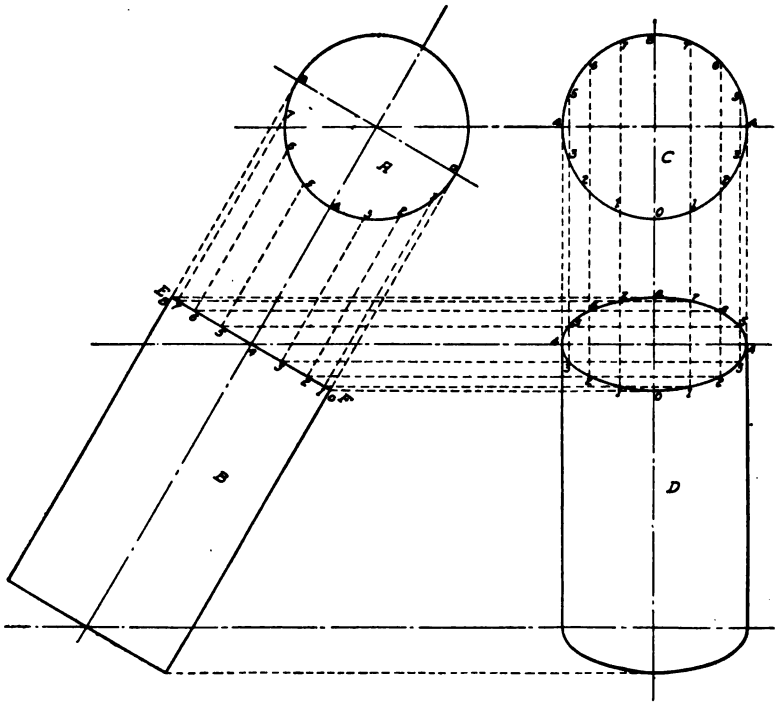


Fig. 129. Method of Finding the Projection, in the Form of an Ellipse, of the Top of a Cylinder Greatly Inclined to a Plane

cylinder. Connecting these two circles with horizontal lines HI and JK, representing the sides of the cylinder, completes the plan view, and the problem is finished.

As the cylinder is at an angle with the horizontal plane, it will be seen that the top and bottom of the cylinder in the plan view are not circles, but ellipses. It is, however, customary to draw them with the compass, as circles, when the angle of the cylinder with the plane is not great.

Cylinder Greatly Inclined to Horizontal Plane. In Fig. 129 the plan and front elevation of the top of the cylinder are drawn at the desired angle with the horizontal plane at A and B, respectively. The plan view at A is then transferred to C. In each of these plan views divide the lower semicircle into a number of equal parts, eight in this case. From the view of A, project the points 0—8, parallel to the center line, down to EF, and then project across to the projection lines drawn vertically down from the points 0—8 in C. The points of intersection of projection lines, correspondingly numbered, form the shape of the ellipse representing the top of the side view of the inclined cylinder D, and the ellipse drawn through these points completes this view. The side lines of the cylinder may now be drawn, and the curve representing the bottom of the side view may easily be copied from the lower half of the ellipse representing the top view. When the points have been located, the ellipses may be drawn through them with the aid of an irregular curve.

ILLUSTRATIVE EXAMPLES

1. *Construct plan and elevation of a regular hexagonal pyramid.* It is evident that two distinct geometrical views are necessary to convey a complete idea of the form of the object; an elevation to represent the sides of the body, and to express its height; and a plan of the upper surface to express the form horizontally.

It is to be observed that this body has an imaginary axis or center line, about which the same parts or segments of the body are equally distant; this is an essential characteristic of all symmetrical figures.

Draw a horizontal dotted line MN for the center line of the plan views, Fig. 130. Then draw a perpendicular ZZ' to MN.

In delineating the pyramid, it is necessary, in the first place, to construct the plan. The point S', where the line ZZ' intersects the line MN, is to be taken as the center of the figure, and from this point, with a radius equal to the side of the hexagon which forms the base of the pyramid, describe a circle, cutting MN in A' and D'. From these points, with the same radius, draw four arcs of circles, cutting the primary circle in four points. These six points being joined by straight lines, will form the figure $A'B'C'D'E'F'$,

which is the base of the pyramid; and the lines $A'D'$, $B'E'$, and $C'F'$, will represent the projections of its edges foreshortened as they would appear in the plan. If this operation has been correctly performed, the opposite sides of the hexagon should be parallel to each other and to one of the diagonals; this should be tested by the application of the square or other instrument proper for the purpose.

By the help of the plan obtained as above described, the vertical

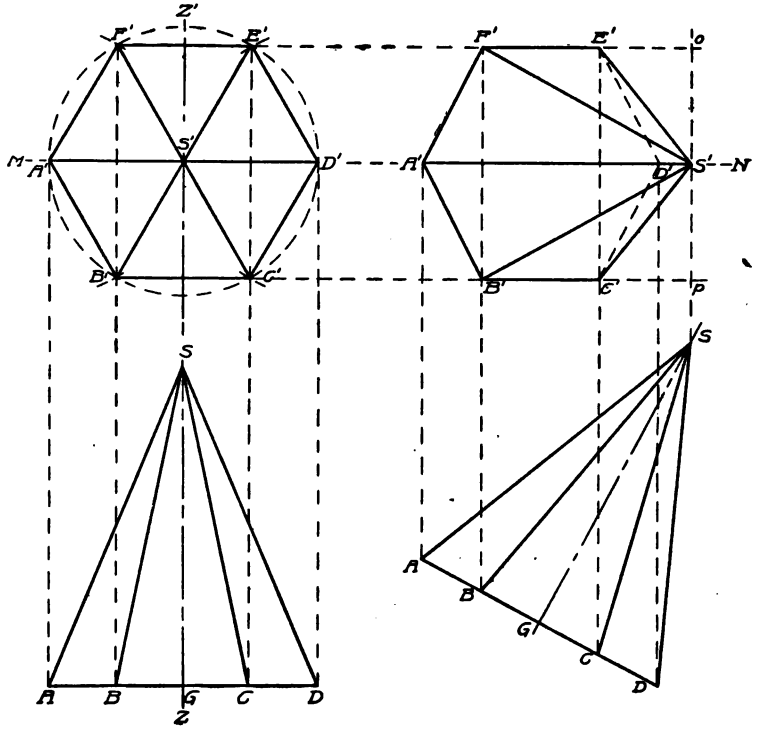


Fig. 130. Construction of Regular Hexagonal Pyramid

projection of the pyramid may be easily constructed. Since it is directly under the plan, it must be projected vertically downward; therefore, from each of points A', B', C', D', drop perpendiculars to AD, the base line of the pyramid in the elevation. The points of intersection, A, B, C, and D, are the true positions of all the angles of the base; and it only remains to determine the height of the pyramid, which is to be set off from the point G to S, and to

draw SA, SB, SC, and SD, which are the only edges of the pyramid visible in the elevation. Of these it is to be remarked that SA and SD alone, being parallel to the vertical plane, are seen in their true length; and, moreover, that from the assumed position of the solid under examination, the points F' and E' being situated in the lines BB' and CC', the lines SB and SC are each the projections of two edges of the pyramid.

2. *Construct the projections of the pyramid, Example 1, having its base set in an inclined position, but with its edges SA and SD still parallel to the vertical plane,* Fig. 130.

It is evident, that with the exception of the inclination, the vertical projection of this solid is precisely the same as in the preceding example, and it is only necessary to show the same view of the pyramid in its new position. For this purpose, after having fixed the position of the point D, draw through this point a straight line DA, making with MN an angle equal to the desired inclination of the base of the pyramid. Then set off the distance DA, equal to that used in Example 1; erect a perpendicular on the center, and set off GS equal to the height of the pyramid. Transfer also from the first example the distance BG and CG to the corresponding points, and complete the figure by drawing the straight lines AS, BS, CS, and DS.

In constructing the plan of the pyramid in this position, it is to be remarked that since the edges SA and SD are still parallel to the vertical plane, and the point D remains unaltered, the projection of the points A, D, and S, will still be in the line MN. The position of A' is determined by the intersection of the perpendicular AA' with MN. The remaining points, B', C', etc., in the projection of the base, are found, in a similar manner, by the intersections raised from the corresponding points in the elevation, with lines drawn parallel to MN, at a distance (set off at o, p) equal to the width of the base. By joining all the contiguous points, the figure $A'B'C'D'E'F'$ is obtained representing the horizontal projection of the base, two of its sides, however, being dotted, as they must be supposed to be concealed by the body of the pyramid. The vertex S having been similarly projected to S', and joined by straight lines to the several angles of the base, the projection of the solid is completed.

INTERSECTIONS

If one surface meets another at some angle, an intersection is produced. Either surface may be plane, or curved. If both are plane, the intersection is a straight line; if one is curved, the intersection is a curve, except in a few special cases; and if both are curved, the intersection is usually curved. In the latter case, the

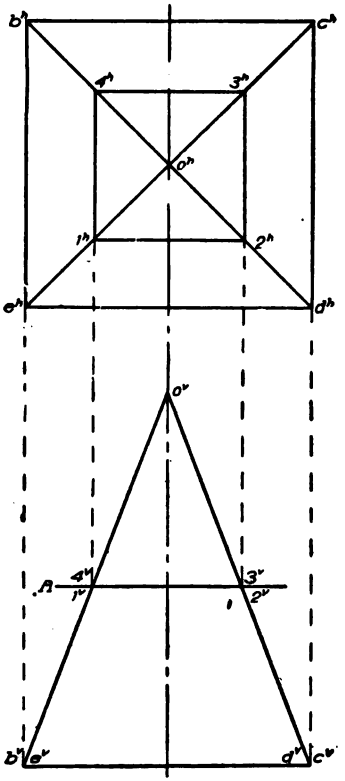


Fig. 131. Intersection of Plane and Square Pyramid

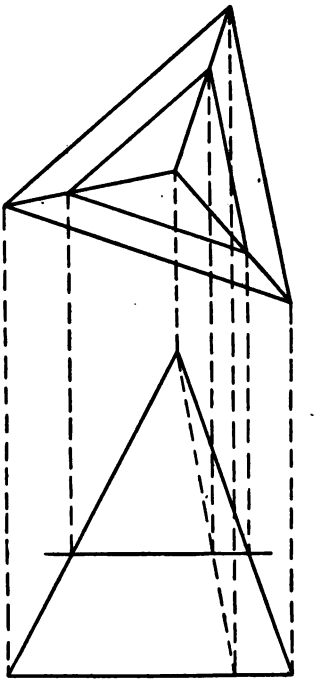


Fig. 132. Intersection of Plane and Triangular Pyramid

entire curve does not always lie in the same planes. If all points of any curve lie in the same plane, it is called a *plane curve.* A plane intersecting a curved surface must always give either a plane curve or a straight line.

Planes with Planes. In Fig. 131 a square pyramid is cut by a plane *A* parallel to the horizontal. This plane cuts from the pyra-

mid a four-sided figure, the four corners of which will be the points where A cuts the four slanting edges of the solid. The plane intersects edge ob at point 4^v in elevation. This point must be found in plan vertically above on the horizontal projection of line ob, that is, at point 4^h. Edge oe is directly in front of ob, so is shown in elevation as the same line, and plane A intersects oe at point 1^v in

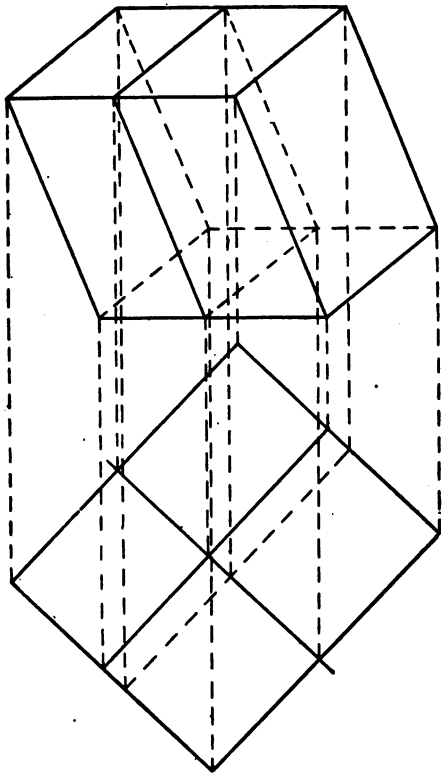


Fig. 133. Intersection of Plane and Prism

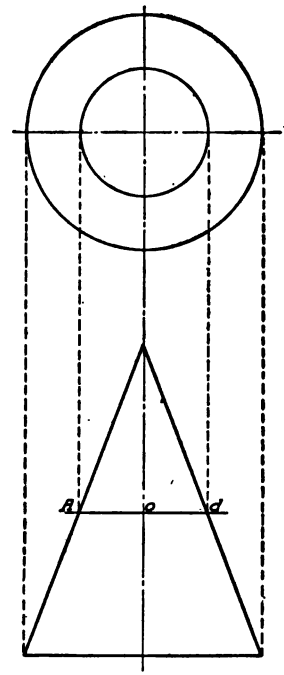


Fig. 134. Intersection of Plane and Cone

elevation, found in plan at 1^h. Points 3 and 2 are obtained in the same way. The intersection is shown in plan as the square 1-2-3-4, which is also its true size as it is parallel to the horizontal plane. In a similar way the intersections are found in Figs. 132 and 133. It will be seen that in these three cases where the planes are parallel to the bases, the sections are of the same shape as the bases, and have their sides parallel to the edges of the bases.

It is an invariable rule that when such a solid is cut by a plane parallel to its base, the section is a figure of the same shape as the base. If then in Fig. 134 a right cone is intersected by a plane parallel to the base the section must be a circle, the center of which in plan coincides with the apex. The radius must equal *od*.

In Fig. 135 and Fig. 136 the cutting plane is not parallel to the base, hence the section will not be of the same shape as the base.

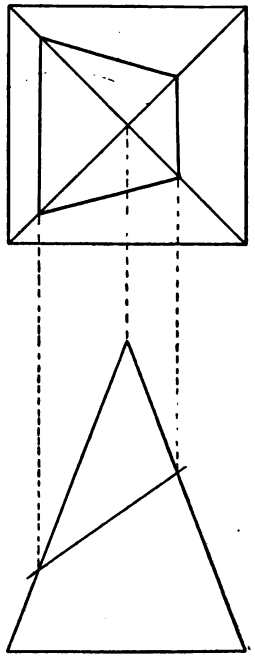


Fig. 135. Intersection of Plane and Square Pyramid

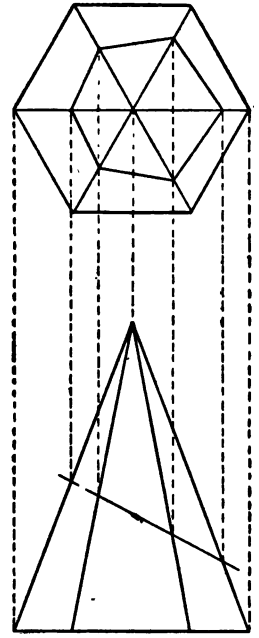


Fig. 136. Intersection of Plane and Hexagonal Pyramid

The intersections are found, however, in exactly the same manner as in the previous figures, by projecting the points where the plane intersects the edges in elevation, on to the other view of the same line.

ILLUSTRATIVE EXAMPLES

1. Find the horizontal projection of a transverse section of the pyramid of Fig. 130, made by a plane perpendicular to the vertical, but inclined at an angle to the horizontal plane of projection; and let all the sides of the base be at an angle with *M N*, Fig. 137.

Having drawn the vertical SS', the center line of the figures, its point of intersection with the line MN is the center of the plan. Since none of the sides of the base are to be parallel with MN, draw a diameter $A'D'$ making the required angle with MN, and from the points A' and D' proceed to set out the angular points of the hexagon, as in Fig. 130. Then join the angular points which are diametrically opposite and project the figure thus obtained upon the vertical plane, as shown.

Now, if the cutting plane be represented by the line ad in the elevation, it is obvious that it will expose, as the section of the pyramid, a polygon whose angular points being the intersections of the various edges with the cutting plane, will be projected in perpendiculars drawn from the points where it meets these edges respectively. From the points a, f, b, etc., raise the perpendiculars aa', ff', bb', etc., to meet the lines $A'D'$, $F'C'$, $B'E'$, etc. When the contiguous points of intersection of these lines are joined, a six-sided figure will be formed which will represent the section required. The edges FS and ES being concealed in the elevation, but necessary for the construction of the plan, have been expressed in dotted lines, as is also the portion of the pyramid situated above the cutting plane which, though supposed to be removed, is necessary in order to draw the lines representing the edges.

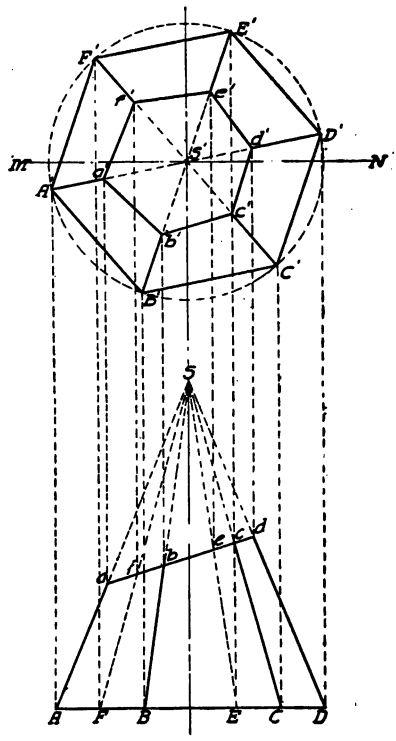


Fig. 137. Frustum of Hexagonal Pyramid

2. Find the horizontal projection of the transverse section of a regular five-sided pyramid, cut by a plane perpendicular to the vertical, but inclined at an angle to the horizontal plane of projection; and let one edge of the pyramid, BS, be in a plane

perpendicular to both the horizontal and the vertical planes of projection, as shown in Fig. 138.

The plan of the pyramid is constructed by describing from the center S' a circle circumscribing the base, and from B' dividing the circumference into five equal parts, and joining the contiguous points of division by straight lines. These form the polygon $A'B'C'D'E'$, whose angles, when joined to the center S', show the projections of the edges of the pyramid. Then, following the method above explained, the elevation and the horizontal projection of the section made by the plane ac are obtained. But that method will not suffice for the determination of the point b', because the perpendicular let fall from the corresponding point b, in the elevation, coincides with the projection of the edge BS. Let the pyramid supposedly be turned a quarter of a revolution round its axis; the line $B'S'$ will then have assumed the position $S'b^2$. Project the point b^2 to b^3, and join Sb^3. Then since the required point must also be conceived to have described a quarter of a circle in a plane parallel to the horizontal plane, and that its new position must be in the line Sb^3, it is obvious that its vertical projection is the point b^4, the intersection of a horizontal line drawn through b with the line Sb^3. The distance bb^4 may then be used to determine the distance from S' to b', and determines the position of the latter point in the plan; or, following a more methodical process, by projecting the point b^4 to b^5, and describing a circle from the center S' passing through b^5, its intersection with $B'S'$ is the point sought.

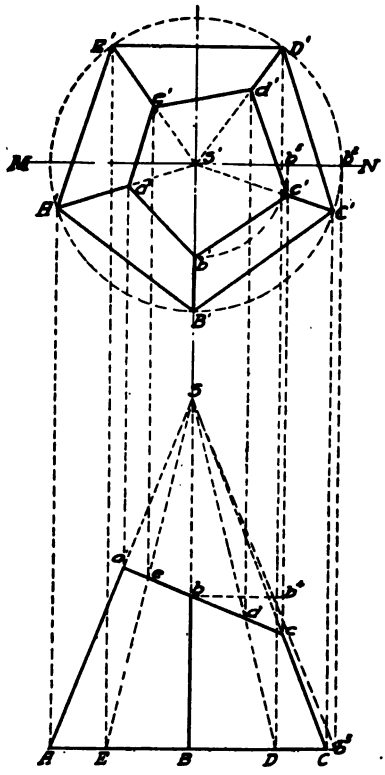


Fig. 138. Frustum of Pentagonal Pyramid

Planes with Cones or Cylinders. Sections cut by a plane from a cone have already been defined as *conic sections*. These sections may be any of the following: two straight lines, circle, ellipse, parabola, hyperbola. All except the parabola and hyperbola may also be cut from a cylinder.

Methods have previously been given for constructing the ellipse, parabola, and hyperbola, without projections; it will now be shown that they may be obtained as actual intersections.

Ellipse. In Fig. 139 the plane cuts the cone obliquely. To find points on the curve in plan take a series of horizontal planes *xyz*, etc., between points c^v and d^v. One of these planes, as *w*, should be taken through the center of *cd*. The points *c* and *d* must be points on the curve, since the plane cuts the two contour elements at these points. Contour elements are those forming the outline. The horizontal projections of the contour elements will be found in a horizontal line passing through the center of the base; hence the horizontal projection of *c* and *d* will be found on this center line, and will be the extreme ends of the curve.

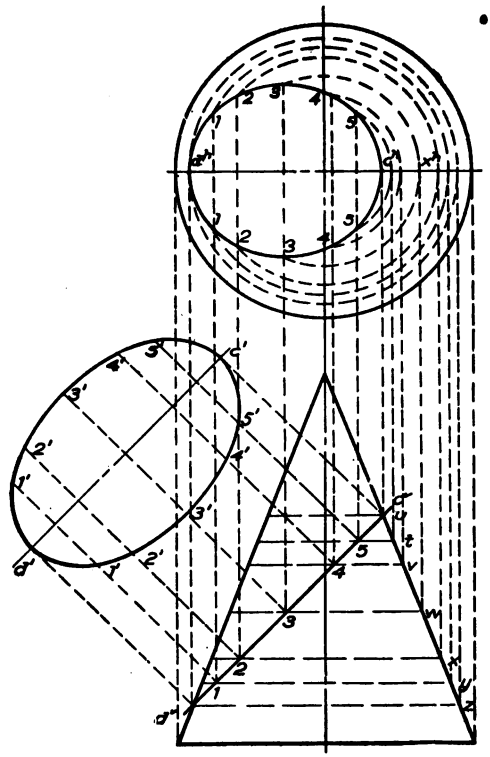


Fig. 139. Ellipse—Section from a Cone

The plane *x* cuts the surface of the cone in a circle, as it is parallel to the base, and the diameter of the circle is the distance between the points where *x* crosses the two contour elements. This circle, lettered *x* on the plan, has its center at the horizontal projection of the apex. The circle *x* and the curve cut by the plane are both on

the surface of the cone, and their vertical projections intersect at the points 2-2. Point 2 on the elevation then represents two points which are shown in plan directly above on the circle x, and are points on the required intersection. Planes y and z, and as many more as may be necessary to determine the curve accurately, are used in the same way. The curve found is an ellipse. The student will readily see that the true size of this ellipse is not shown in the plan, for the plane containing the curve is not parallel to the horizontal.

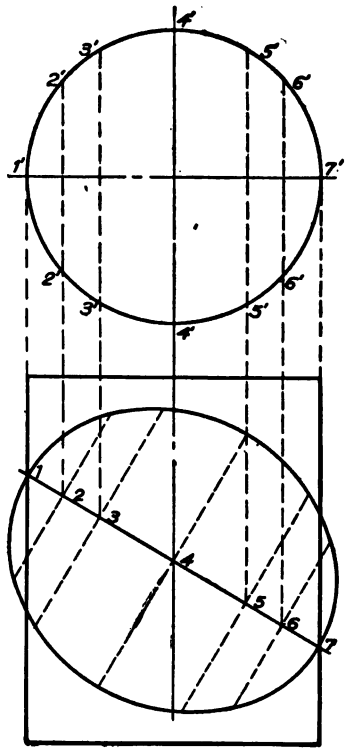


Fig. 140. Ellipse—Section from a Cylinder

In order to find the *actual size of the ellipse*, it is necessary to place its plane in a position parallel either to the vertical or to the horizontal. The actual length of the long diameter of the ellipse must be shown in elevation, $c^v d^v$, because the line is parallel to the vertical plane. The plane of the ellipse then may be revolved about $c^v d^v$ as an axis until it becomes parallel to V, when its true size will be shown. For the sake of clearness of construction, $c^v d^v$ is imagined moved over to the position $c' d'$, parallel to $c^v d^v$. The lines 1-1, 2-2, 3-3 on the plan show the true width of the ellipse, as these lines are parallel to H, but are projected closer together than their actual distances. In elevation these lines are shown as the points 1, 2, 3, at their true distance apart. Hence if the ellipse is revolved around its axis $c^v d^v$, the distances 1-1, 2-2, 3-3 may be laid off on lines perpendicular to $c^v d^v$, and the true size of the figure be shown.

In Fig. 140 a plane cuts a cylinder obliquely. This is a simpler case, as the horizontal projection of the curve coincides with the base of the cylinder. To obtain the true size of the section, which is an ellipse, any number of points are assumed on the plan and

projected down on the cutting plane, at 1, 2, 3, etc. The lines drawn through these points perpendicular to 1′-7′ are made equal in length to the corresponding distances 2′-2′, 3′-3′, etc., on the plan, because 2′-2′ is the true width of curve at 2.

Parabola. If a cone is intersected by a plane which is parallel to only one of the elements, as in Fig. 141, the resulting curve is

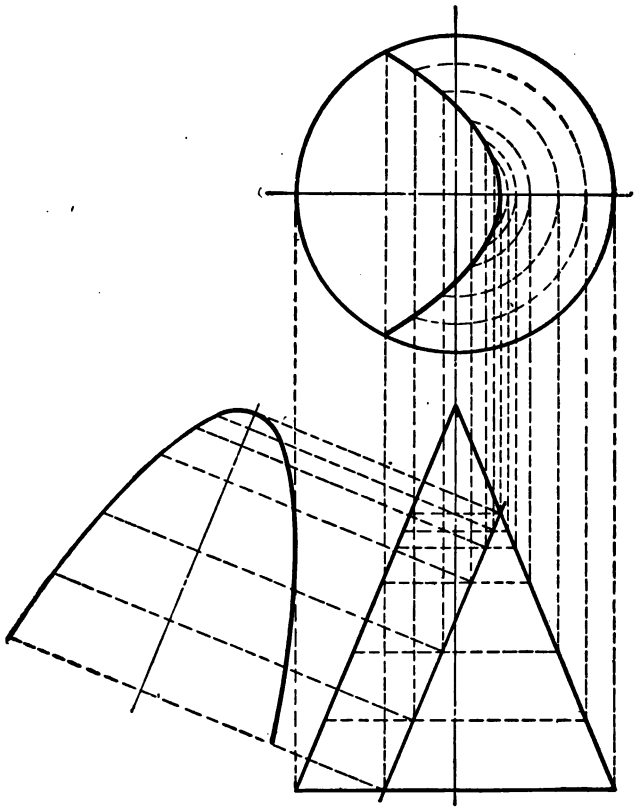


Fig. 141. Parabola—Section from a Cone

the *parabola*, the construction of which is exactly similar to that for the ellipse, as given in Fig. 139. If the intersecting plane is parallel to more than one element, or is parallel to the axis of the cone, a hyperbola is produced.

In Fig. 142, the vertical plane *A* is parallel to the axis of the cone. In this instance the curve when found will appear in its true

size, as plane A is parallel to the vertical. Observe that the highest point of the curve is found by drawing the circle X on the plan tangent to the given plane. One of the points where this circle crosses the diameter is projected down to the contour element of the cone, and the horizontal plane X drawn. Intermediate planes Y, Z, etc., are chosen, and corresponding circles drawn in plan. The points where these circles are crossed by the plane A are points on the curve, and these points are projected down to the elevation on the planes Y, Z, etc.

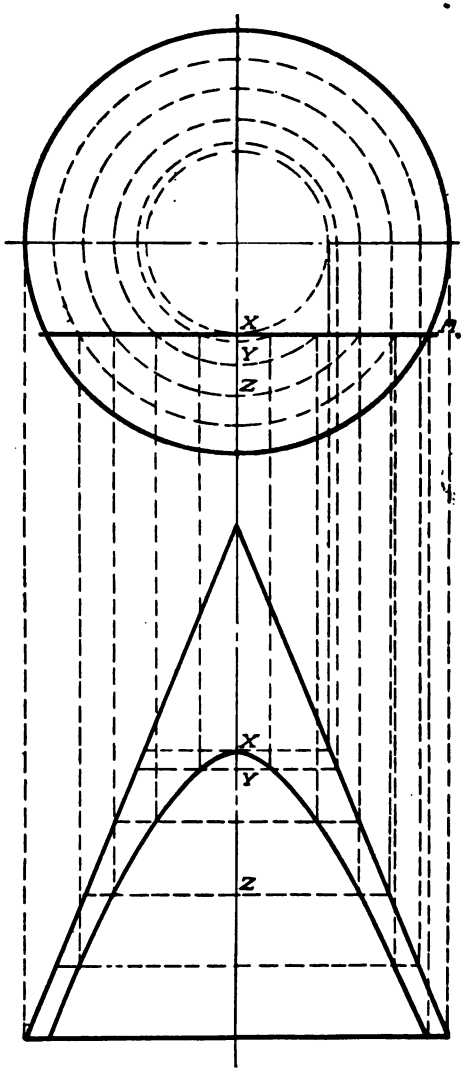


Fig. 142. Hyperbola—Section from a Cone

DEVELOPMENT OF SURFACES

General Details of Process. A surface may be considered as formed by the motion of a line. Any length of line moved sidewise in any direction will form a surface, of a width equal to the length of the line, and of a length equal to the distance over which the line is moved. There are two different classes of surfaces; namely, those formed by a moving straight line, and those formed by a moving curved line.

In some construction work, patterns of different faces or of the whole surface must be made; in stone cutting, for example,

there must be a pattern giving the shape of any irregular surface, and in sheet-metal work a pattern must be made such that, when a sheet is cut, it can be so formed that it will be of the same shape as the original object.

This pattern making, or the laying out of a complete surface on one plane, is called the development of the surface. Any surface

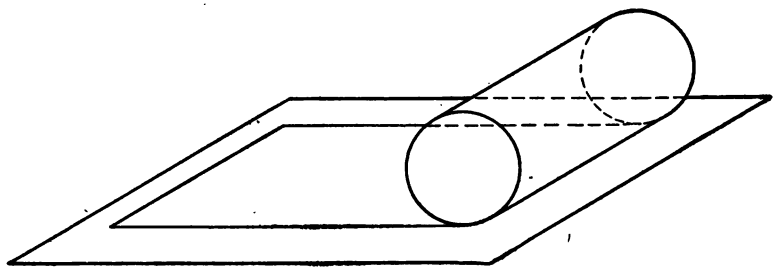


Fig. 143. Development of a Right Cylinder Rolled Out on a Plane

which can be smoothly wrapped about by a sheet of paper, can be developed. Figures made up of planes and single curved surfaces only would be of this nature. Double curved surfaces and warped surfaces cannot be developed, and patterns of such surfaces, when desired, must be made by an approximate method which requires two or more pieces to make the complete pattern.

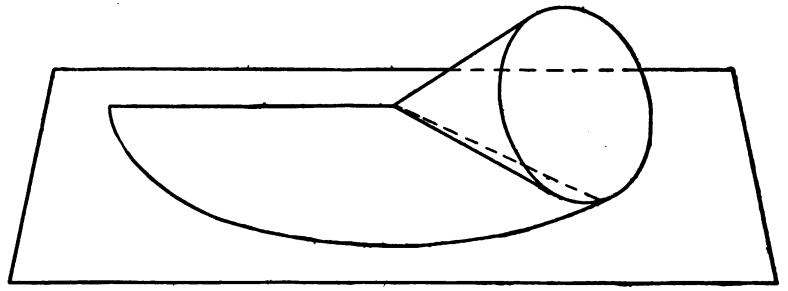


Fig. 144. Development of a Right Cone Rolled Out on a Plane

By finding the true size of all the faces of an object made up of planes, and joining them in order at their common edges, the developed surface will be formed. The best way to do this is to find the true length of the edges of the object.

Right Cylinder. In Fig. 143 is represented a right cylinder rolling on a plane. The development is formed by one complete

revolution of the cylinder and is a rectangle, the width being equal to the height of the cylinder and the length to the circumference.

Right Cone. In Fig. 144 is represented a right cone rolling out its development, which is a sector of a circle. The arc equals the circumference of the circle forming the base of the cone, and the radius equals the slant height.

The projections of any object must be drawn before the development can be made, but it is necessary only to draw such views as are required for finding the lengths of elements, and true sizes of cut surfaces.

Rectangular Prism. In order to find the development of the rectangular prism in Fig. 145, the back face, 1-2-7-6, is supposed

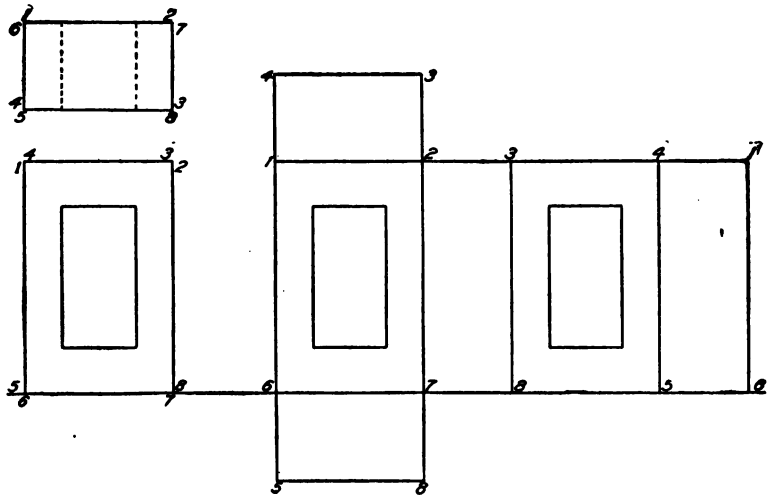


Fig. 145. Development of Hollow Rectangular Prism

to be placed in contact with some plane, then the prism turned on the edge 2-7 until the side 2-3-8-7 is in contact with the same plane, and this process continued until all four faces have been placed on the same plane. The rectangles 1-2-3-4 and 6-7-8-5 are for the top and bottom, respectively. The development then is the exact size and shape of a covering for the prism. If a rectangular hole is cut through the prism, the openings in the front and back faces will be shown in the development in the centers of the two broad faces.

The development of a right prism, then, consists of as many rectangles joined together as the prism has sides, these rectangles being the exact size of the faces of the prism, and in addition two polygons the exact size of the bases. It will be found helpful in developing a solid to number or letter all of the corners on the projections, then designate each face when developed in the same way as in the figure.

Cone. If a cone be placed on its side on a plane surface, one element will rest on the surface. If now the cone be rolled on the

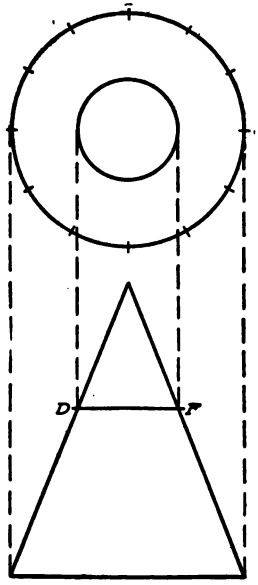


Fig. 146. Plan and Elevation of Cone

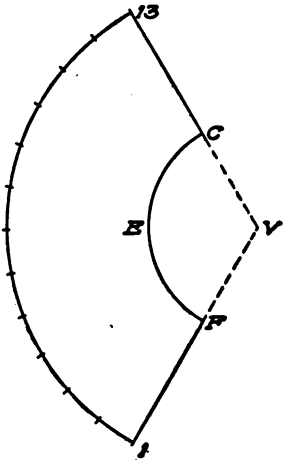


Fig. 147. Development of Cone

plane, the vertex remaining stationary until the same element is in contact again, the space rolled over will represent the development of the convex surface of the cone. Fig. 146 is a cone cut by a plane parallel to the base. In Fig. 147, let the vertex of the cone be placed at V, and one element of the cone coincide with $VF1$. The length of this element is taken from the elevation, Fig. 146, of either contour element. All of the elements of the cone are of the same length, so that when the cone is rolled, each point of the base as it touches the plane will be at the same distance from the vertex. From this it follows that in the development of the base,

the circumference will become the arc of a circle of radius equal to the length of an element, and of a length equal to the distance around the base. To find this length divide the circumference of the base in the plan into any number of equal parts, say twelve, and lay off twelve such spaces, 1 . . . . 13 along an arc drawn with radius equal to $V1$; join 1 and 13 with V, and the resulting sector is the development of the cone from vertex to base. In order to represent on the development the circle cut by the section plane DF, draw, from the vertex V as a center and with VF as a radius, the arc FC. The development of the frustum of the cone will be a portion of a circular ring. This of course does not include the development of the bases, which would be simply two circles the same sizes as shown in plan.

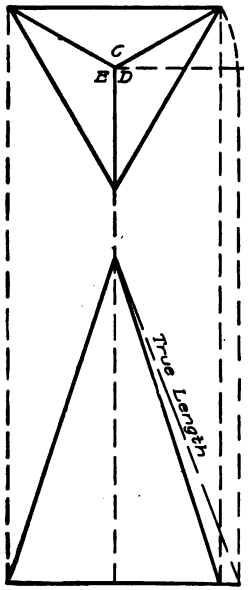


Fig. 148. Plan and Elevation of Triangular Pyramid

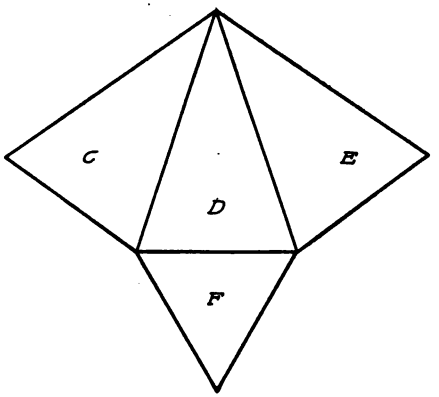


Fig. 149. Development of Triangular Pyramid

Regular Triangular Pyramid. Fig. 148 represents the plan and elevation of a regular triangular pyramid, and Fig. 149 its development. If face C is placed on the plane its true size will be shown in the development. The true length of the base of triangle C is shown in the plan. As the slanting edges, however, are not parallel to the vertical, their true length is not shown in elevation but must be obtained by the method given on page 88, as indicated in Fig. 148. The triangle may now be drawn in its full size at C in the development, and as the pyramid is regular, two other equal triangles,

D and *E*, may be drawn to represent the other sides. These, together with the base *F*, constitute the complete development.

Truncated Circular Cylinder. If a truncated circular cylinder is to be developed, or rolled upon a plane, the elements, being parallel, will appear as parallel lines, and the base line being perpendicular to the elements, will appear as a straight line of length equal to the circumference of the base. The base of the cylinder in Fig. 150 is divided into twelve equal parts, 1, 2, 3, etc., and commencing at point 1 on the development, these twelve equal spaces are laid off along the straight line, giving the total width.

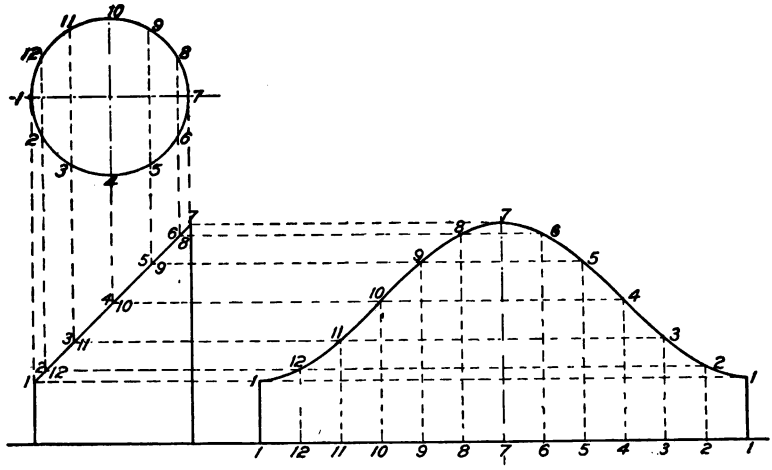


Fig. 150. Projections and Development of Truncated Cylinder

Draw in elevation the elements corresponding to the various divisions of the base, and note the points where they intersect the oblique plane. As the cylinder is rolled beginning at point 1, the successive elements, 1, 12, 11, etc., will appear at equal distances apart, and equal in length to the lengths of the same elements in elevation. Thus point number 10 on the development is found by projecting horizontally across from 10 in elevation. It will be seen that the curve formed is symmetrical, the half on the left of 7 being similar to that on the right. The development of any similar surface may be found in the same manner.

The principle of cylinder development is used in laying out elbow joints, pipe ends cut off obliquely, etc. In Fig. 151 is shown

plan and elevation of a three-piece elbow and collar, and developments of the four pieces. In order to construct the various parts making up the joint, it is necessary to know what shape and size must be marked out on the flat sheet metal so that when cut out and rolled up the three pieces will form cylinders with the ends fitting together as required. Knowing the kind of elbow desired, first draw the plan and elevation, and from these make the develop-

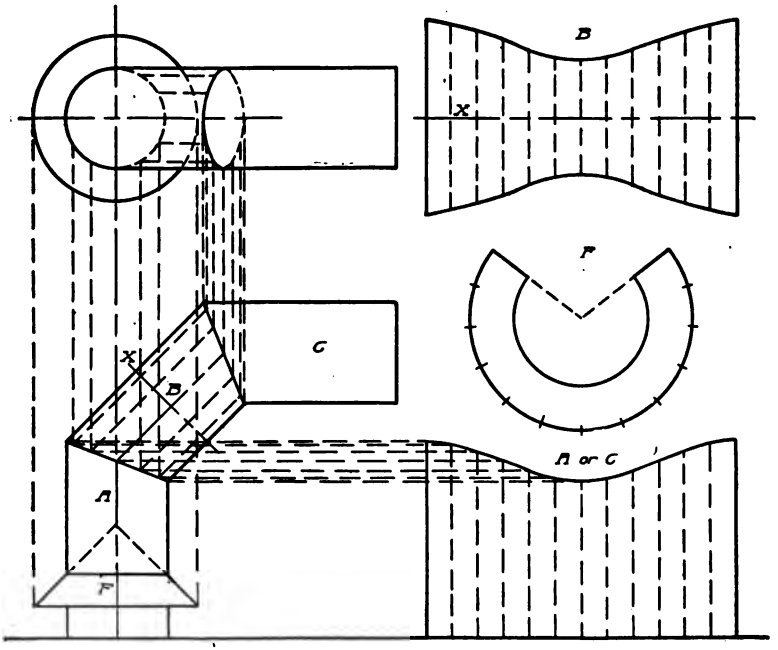


Fig. 151. Plan, Elevation, and Development of Three-Piece Elbow and Collar

ments. Let the lengths of the three pieces *A*, *B*, and *C* be the same on the upper outside contour of the elbow, the piece *B* at an angle of 45 degrees; the joint between *A* and *B* bisects the angle between the two lengths, and in the same way the joint between *B* and *C*. The lengths *A* and *C* will then be the same and one pattern will answer for both. The development of *A* is made exactly as just explained for Fig. 150, and this is also the development of *C*.

It should be borne in mind that in developing a cylinder the base must always be at right angles to the elements, and if the cylinder as given does not have such a base, it becomes necessary

to cut the cylinder by a plane perpendicular to the elements, and use the intersection as a base. This point must be clearly understood in order to proceed intelligently. A section at right angles to the elements is the only section which will unroll in a straight line, and is, therefore, the section from which the other sections must be developed. As *B*, Fig. 151, has neither end at right angles to its length, the plane *X* is drawn at the middle and perpendicular to the length. *B* has the same diameter as *C* and *A*, so the section cut by *X* will be a circle of the same diameter as the base of *A*, and is shown in the development at *X*.

The elements on *B* are drawn from the points where the elements on the elevation of *A* meet the joint between *A* and *B*, and are equally spaced as shown on the plan of *A*. Commencing with the left-hand element in *B*, the length of the upper element between *X* and the top corner of the elbow is laid off above *X*, giving the first point in the development of the end of *B* fitting with *C*. The lengths of the other elements in the elevation of *B* are measured in the same way and laid off from *X*. The development of the other end of the piece *B* is laid off below *X*, using the same distances, since *X* is half way between the ends. The development of the collar is simply the development of the frustum of a cone, which has already been explained, Fig. 147. The joint between *B* and *C* is shown in plan as an ellipse, the construction of which the student should be able to understand from a study of the figure.

ISOMETRIC PROJECTION

Isometric of a Cube. In orthographic projection an object has been represented by two or more projections; another system, called isometrical drawing, is often used to show in one view the three dimensions of an object, length (or height), breadth, and thickness. An isometrical drawing of an object, as a cube, is called for brevity the isometric of the cube.

To obtain a view which shows the three dimensions in such a way that measurements may be taken from them, draw the cube in the simple position shown at the left, Fig. 152, with two faces parallel to *V;* the diagonal from the front upper right-hand corner to the back lower left-hand corner is indicated by the dotted line. Swing the cube around until the diagonal is parallel with *V*, as shown in the

second position. Here the front face is at the right. In the third position the lower end of the diagonal has been raised so that it is parallel to H, becoming thus parallel to both planes. The plan is found by the principles of projection, from the elevation and the preceding plan. The front face is now the lower of the two faces shown in the elevation. From this position the cube is swung around, using the corner as a pivot, until the diagonal is perpendicular to V but still parallel to H. The plan remains the same, except as regards position; while the elevation, obtained by projecting across from the previous elevation, gives the isometrical projection of the cube. The front face is now at the left.

Distinction between Isometric Projection and Isometric Drawing. In the last position, as one diagonal is perpendicular to V, it follows

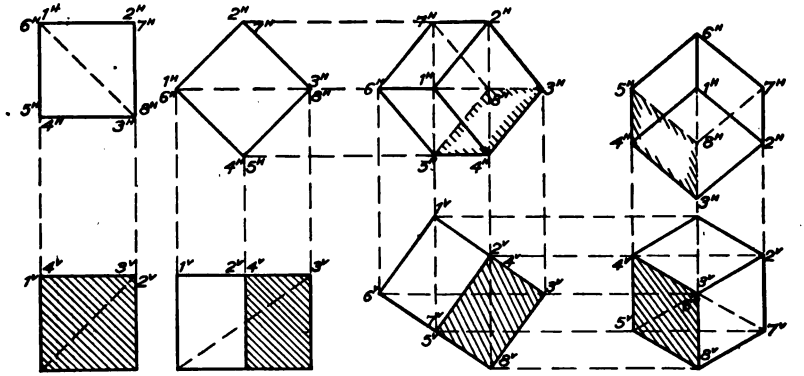


Fig. 152. Development of an Isometric of a Cube

that all the faces of the cube make equal angles with V, hence are projected on that plane as equal parallelograms. For the same reason all the edges of the cube are projected in elevation in equal lengths, but, being inclined to V, appear shorter than they actually are on the object. Since they are all equally foreshortened and since a drawing may be made at any scale, it is customary to make all the isometrical lines of a drawing full length. This will give the same proportions, and is much the simpler method. Herein lies the distinction between an isometric projection and an isometric drawing.

It will be noticed that the figure may be inscribed in a circle, and that the outline is a perfect hexagon. Hence the lines showing

breadth and length are 30-degree lines, while those showing height are vertical.

True Length of Lines. Fig. 153 shows the isometric of a cube 1 inch square. All of the edges are shown in their true length, hence

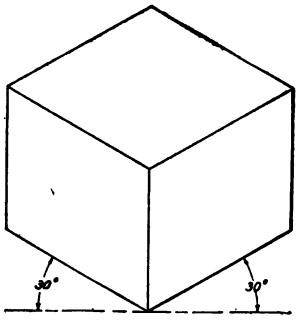


Fig. 153. Isometric of a Cube

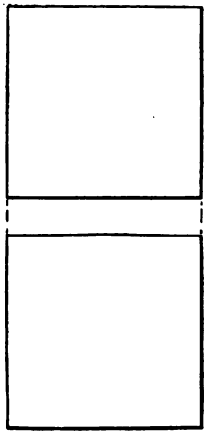


Fig. 154. Plan and Elevation of a Cube

all the surfaces appear of the same size. In the figure the edges of the base are inclined at 30 degrees with a T-square line, but this is not always the case. For rectangular objects, such as prisms, cubes, etc., the base edges are at 30 degrees only when the prism or cube is supposed to be in the simplest possible position. The cube in Fig. 153 is supposed to be in the position indicated by plan and elevation in Fig. 154, that is, standing on its base, with two faces parallel to the vertical plane.

If the isometric of the cube in the position shown in Fig. 155 were required, it could not be drawn with the base edges at 30 degrees; neither would these edges appear in their true lengths. It

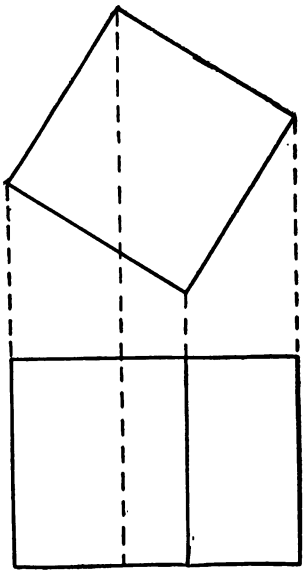


Fig. 155. Cube of Fig. 154 Rotated 30 Degrees with Vertical Plane

follows, then, that in isometrical drawing, true lengths appear only as 30-degree lines or as vertical lines. Edges or lines that in actual projection are either parallel to a T-square line or perpendicular to V, are drawn in isometric as 30-degree lines, full length; and those that are actually vertical are made vertical in isometric, also full length.

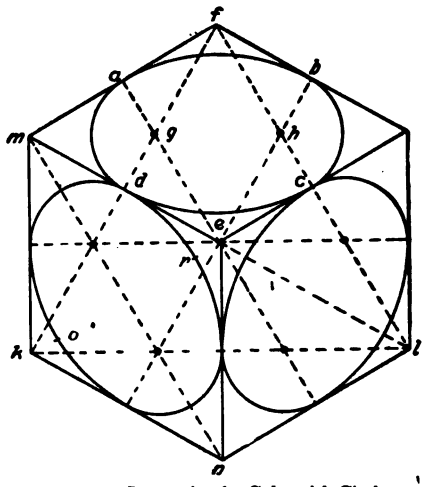


Fig. 156. Isometric of a Cube with Circles Inscribed on its Faces

Three Isometric Axes. In Fig. 152, lines such as the front vertical edges of the cube and the two base edges are called the *three isometric axes*. The isometric of objects in oblique positions, as in Fig. 155, can be constructed only by reference to their projections, by methods which will be explained in the section on "Oblique Projection", page 123.

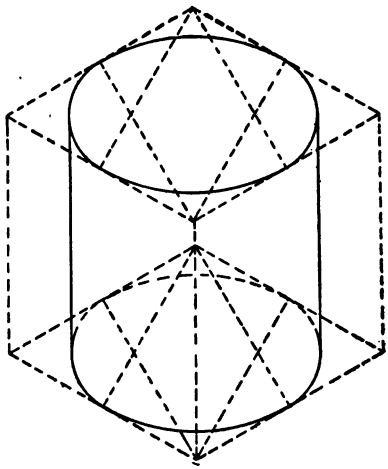


Fig. 157. Isometric of a Cylinder

Applications of Isometric Projections. In isometric drawing small rectangular objects are more satisfactorily represented than large curved ones. In woodwork, mortises and joints and various parts of framing are well shown in isometric. This system is used also to give a kind of bird's-eye view of mills or factories. It is also used in making sketches of small rectangular pieces of machinery, where it is desirable to give shape and dimensions in one view.

Characteristics of Various Isometrics. *Cube with Inscribed Circles.* Fig. 156 shows a cube with circles inscribed in the top and two side faces. The isometric of a circle is an ellipse, the

exact construction of which would necessitate finding a number of points; for this reason an approximate construction by arcs of circles is often made. In the method, Fig. 156, four centers are used. Considering the upper face of the cube, lines are drawn from the obtuse angles f and e to the centers of the opposite sides. The intersections of these lines give points g and h, which serve as centers for the ends of the ellipse. With g as center and radius ga, the arc ad is drawn, and with f as center and radius fd, the arc

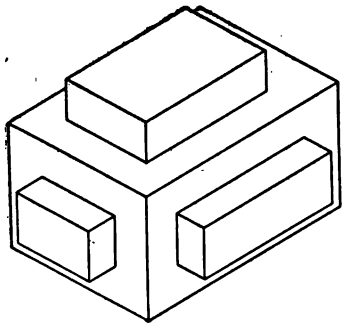


Fig. 158. Isometric of a Wooden Block

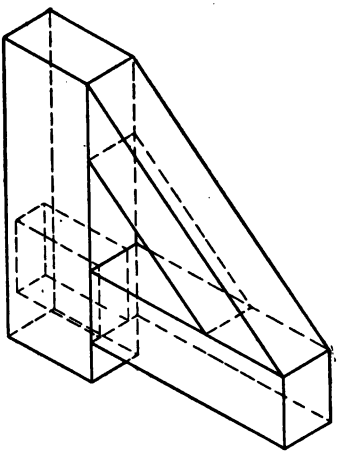


Fig. 159. Isometric of a Wooden Brace

dc is drawn; the ellipse is finished by using centers h and e. This construction is applied to all three faces.

Cylinder. Fig. 157 is the isometric of a cylinder standing on its base.

Blocks. Fig. 158 represents a block with smaller blocks projecting from three faces.

Framework. Fig. 159 shows a framework of three pieces, two at right angles and a slanting brace. The horizontal piece is mortised into the upright as indicated by the dotted lines.

House. In Fig. 160 the isometric outline of a house is represented, showing a dormer window and a partial hip roof; ab is a hip rafter, cd a valley. Let the pitch of the main roof be shown at B, and let m be the middle point of the top of the end wall of the house. Then, by measuring vertically up a distance ml equal to the vertical

height an shown at B, a point on the line of the ridge will be found at l. Line li is equal to bh, and ih is then drawn. Let the pitch of the end roof be given at A. This shows that the peak of the roof, or the end a of the ridge, will be back from the end wall a distance equal to the base of the triangle at A. Hence, lay off from l this distance, giving point a, and join a with b and x.

The height ke of the ridge of the dormer roof is known, and it must be found where this ridge will meet the main roof. The ridge must be a 30-degree line as it runs parallel to the end wall of the house and to the ground. Draw from e a line parallel to bh to meet a vertical through h and f. This point is in the vertical plane of

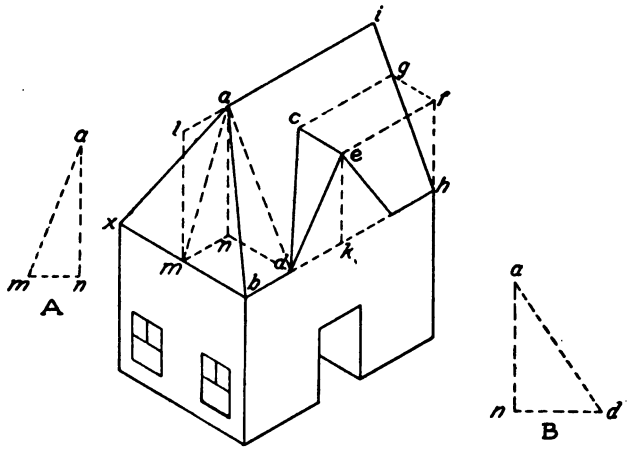


Fig. 160. Isometric Outline of a House

the end wall of the house, hence in the plane of ih. If now a 30-degree line be drawn from f parallel to xb, it will meet the roof of the house at g. The dormer ridge and fg are in the same horizontal plane, hence will meet the roof at the same distance below the ridge ai. Therefore draw the 30-degree line gc, and connect c with d.

Box with Cover. In Fig. 161 a box is shown with the cover opened through 150 degrees. The right-hand edge of the bottom shows the width, the left-hand edge shows the length and the vertical edge shows the height. The short edges of the cover are not isometric lines, hence are not shown in their true lengths; neither is the angle through which the cover is opened represented in its actual size.

The corners of the cover must then be determined by co-ordinates from an end view of the box and cover. As the end of the cover

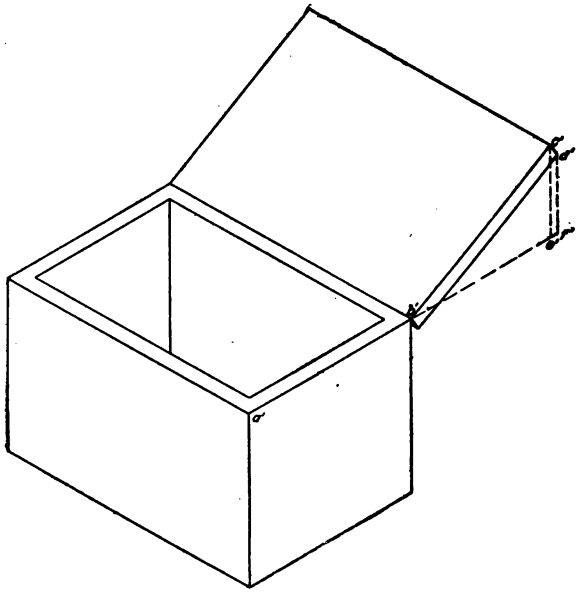


Fig. 161. Isometric of a Box and Cover

is in the same plane as the end of the box, the simple end view as shown in Fig. 162 will be sufficient. Extend the top of the box to the right, and from c and d let fall perpendiculars on ab produced, giving the points e and f. The point c may be located by means of the two distances or co-ordinates be and ec, and these distances will appear in their true lengths in the isometric view. Hence produce $a'b'$ to e' and f'; and from these points draw verticals $e'c'$ and $f'd'$; make $b'e'$ equal to be, $e'c'$ equal to ec; and similarly for d'. Draw the lower edge parallel to $c'd'$ and equal to it in length, and connect with b'.

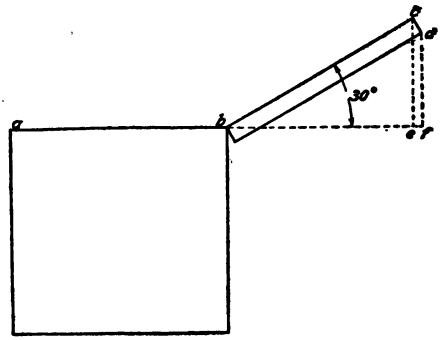


Fig. 162. End View of Box Shown in Fig. 161

It will be seen that in isometric drawing parallel lines always appear parallel. It is also true that lines divided proportionally maintain this same relation in isometric drawing.

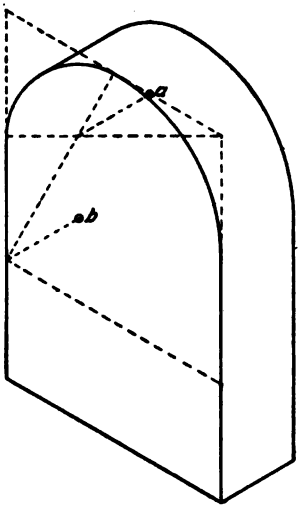


Fig. 163. Isometric of a Prism with Semicircular Top

Prism with Semicircular Top. Fig. 163 shows a block or prism with a semicircular top. Find the isometric of the square circumscribing the circle, then draw the curve by the approximate method. The centers for

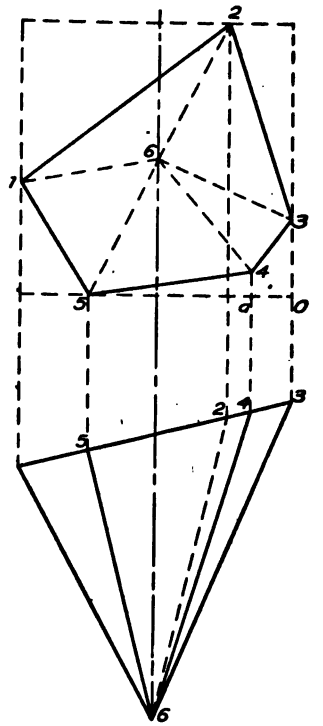


Fig. 164. Plan and Elevation of Oblique Pentagonal Pyramid

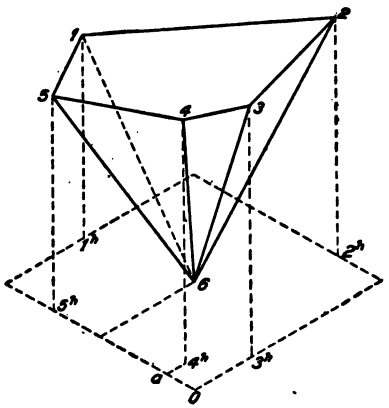


Fig. 165. Isometric of Fig. 164

the back face are found by projecting the front centers back 30 degrees equal to the thickness of the prism, as shown at *a* and *b*.

Pyramid. The plan and elevation of an oblique pentagonal pyramid are shown in Fig. 164. It is evident that none of the edges

of the pyramid can be drawn in isometric as either vertical or 30-degree lines; hence a system of co-ordinates must be used as shown in Fig. 165. This problem illustrates the most general case; and to locate some of the points three co-ordinates must be used, two at 30 degrees and one vertical.

Circumscribe, about the plan of the pyramid, a rectangle which shall have its sides respectively parallel and perpendicular to a T-square line.

The isometric of this rectangle can be drawn at once with 30-degree lines, as shown in Fig. 165, o being the same point in both figures. The horizontal projection of point 3 is found in isometric at 3^h, at the same distance from o as in the plan. That is, *any distance which in plan is parallel to a side of the circumscribing rectangle, is shown in isometric in its true length and parallel to the corresponding side of the isometric rectangle.* If point 3 were on the horizontal plane its isometric would be 3^h, but the point is at the vertical height above H given in the elevation; hence, lay off above 3^h this vertical height, obtaining the actual isometric of the point. To locate point 4, draw $4a$ parallel to the side of the rectangle; then lay off oa and $a4^h$, giving what may be called the isometric plan of 4. The

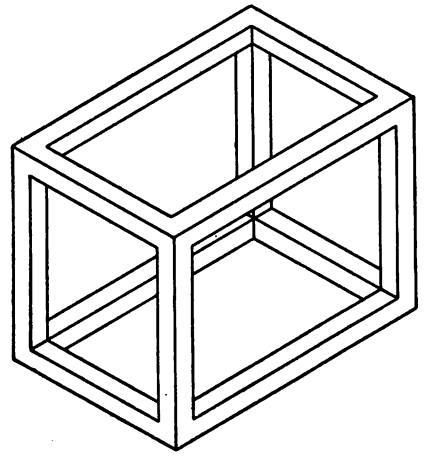


Fig.166. Isometric of a Skeleton of a Box

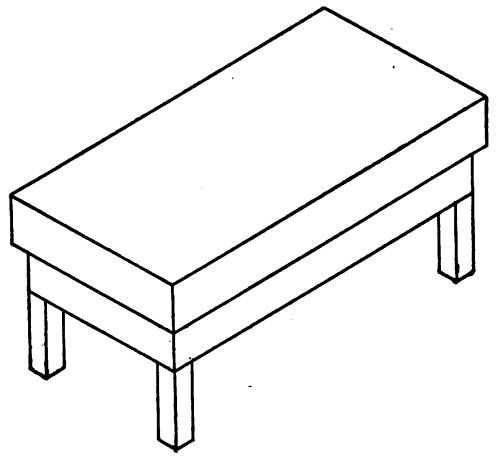


Fig. 167. Isometric of a Carpenter's Bench

vertical height taken from the elevation locates the isometric of the point.

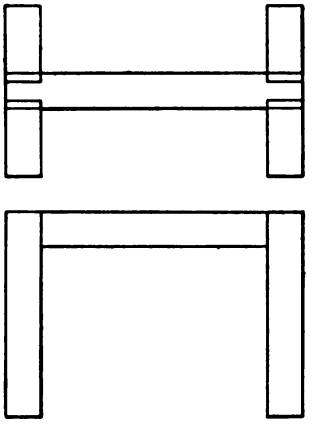


Fig. 168. Plan and Elevation of Sawhorse

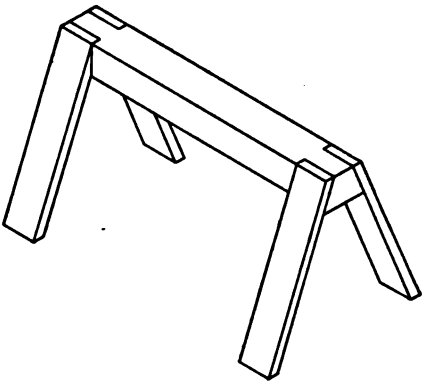


Fig. 169. Isometric of Fig. 168

In like manner all the corners of the pyramid, including the apex, are located. The rule is, *locate first in isometric the horizontal*

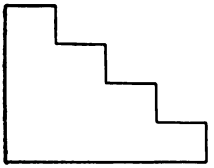


Fig. 170. End Elevation of Stairs

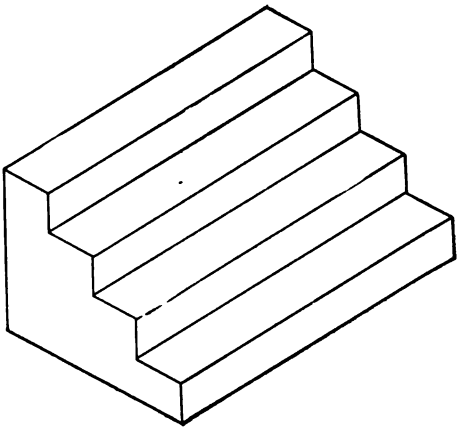


Fig. 171. Isometric of Stairs

projection of a point by one or two 30-degree co-ordinates; then vertically above this point, locate its height as taken from the elevation.

Figs. 166 to 173 give examples of the isometric of various objects.

Fig. 168 is the plan and elevation, and Fig. 169 the isometric, of a carpenter's sawhorse.

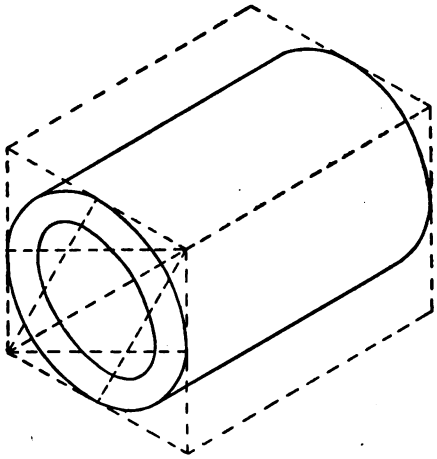


Fig. 172. Isometric of a Hollow Cylinder

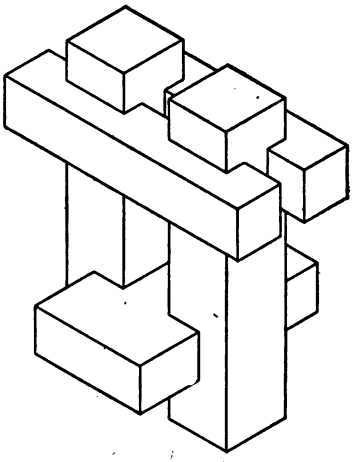


Fig. 173. Isometric of a Wooden Model

OBLIQUE PROJECTION

Comparison with Isometric Projection. In oblique projection, as in isometric, the end sought for is the same—a more or less complete representation, in one view, of any object. Oblique projection differs from isometric in that one face of the object is represented as if parallel to the vertical plane of projection, the others inclined to it. Another point of difference is that oblique projection cannot be deduced from orthographic projection, as is isometric.

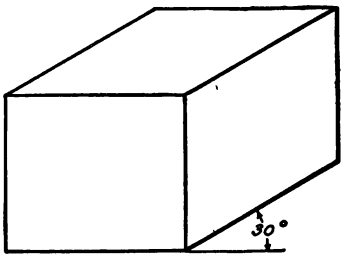


Fig. 174. Oblique View of Cube at 30 Degrees

Characteristics of Method. In oblique projection all lines in the front face are shown in their true lengths and in their true relation to one another, and lines which are perpendicular to this front face are shown in their true lengths at any angle that may be desired for any particular case. Lines not in the plane of the front face nor perpendicular to it must be determined by co-ordinates, as in isometric. It will be seen at once that this system

possesses some advantages over the isometric, as, for instance, in the representation of circles, as any circle or curve in the front face is actually drawn as such. Fig. 174, Fig. 175, and Fig. 176 show a cube in oblique projection with the 30-degree, 45-degree, and 60-degree slant, respectively. Fig. 177 shows a hollow cylinder in oblique projection. Figs 178, 179, 180, 182 are other examples of oblique projections. Fig. 180 is a crank arm.

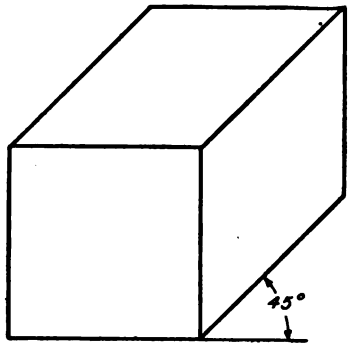


Fig. 175. Oblique View of Cube at 45 Degrees

The method of using co-ordinates for lines of which the true lengths are not shown, is illustrated by Figs 181 and 182. Fig. 182 represents the oblique projection of the two joists shown in plan and elevation in Fig. 181. The dotted lines in the elevation, Fig. 181, show the heights of the corners above the horizontal stick. The feet of these perpendiculars give the horizontal distances of the top corners from the end of the horizontal piece.

In Fig. 182 lay off from the upper right-hand corner of the front end a distance equal to the distance between the front edge of the

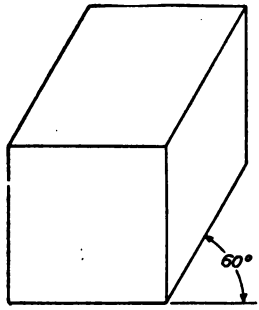


Fig. 176. Oblique View of Cube at 60 Degrees

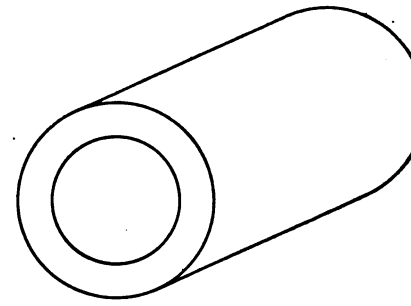


Fig. 177. Oblique View of Hollow Cylinder

inclined piece and the front edge of the bottom piece, Fig. 181. From this point draw a dotted line parallel to the length. The horizontal distances from the upper left corner to the dotted perpendicular are then marked off on this line. From these points verticals

are drawn, and made equal in length to the dotted perpendiculars of Fig. 181, thus locating two corners of the end.

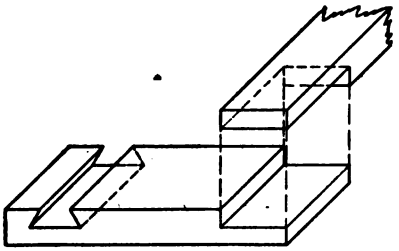


Fig. 178. Oblique View of a Miter Joint

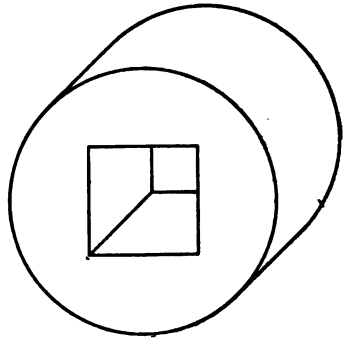


Fig. 179. Oblique View of Cylinder

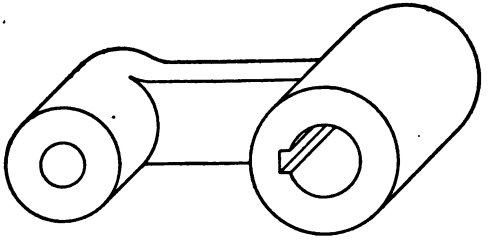


Fig. 180. Oblique View of Crank Shaft

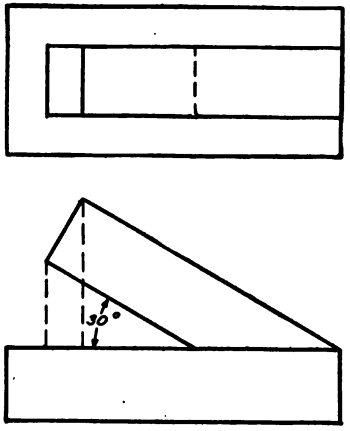


Fig. 181. Plan and Elevation of Wooden Brace

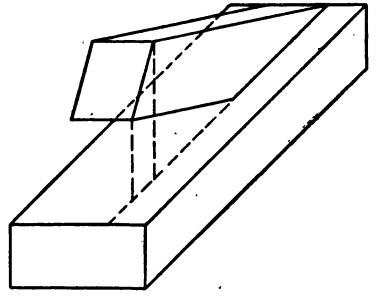


Fig. 182. Oblique View of Wooden Brace

LINE SHADING

Object of Line Shading. In finely finished drawings it is frequently desirable to make the various parts more readily seen by showing the graduations of light and shade on the curved surfaces. This is especially true of such surfaces as cylinders, cones, and spheres. The effect is obtained by drawing a series of parallel or converging lines on the surface at varying distances from one another. Sometimes draftsmen, themselves, vary the width of the lines. These lines are farther apart on the lighter portion of the surface, and closer together and heavier on the darker part.

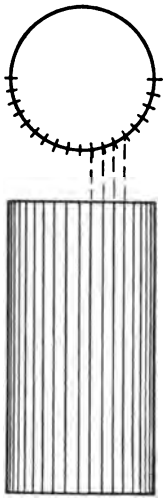


Fig. 183. Plan and Shaded Elevation of Cylinder

Fig. 183 shows a cylinder with elements drawn on the surface equally spaced on the plan. On account of the curvature of the surface, however, the elements are not equally spaced on the elevation, in order to give the effect of the graduations of light on the curved surface. The result is that in drawing the elevation of the cylinder, the distances between the elements are made gradually less from the center toward each side, thus giving a correct representation of the convexity of the cylinder. This effect is intensified by making the

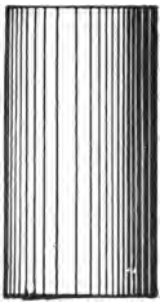


Fig. 184. Shaded Vertical Cylinder

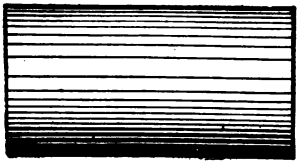


Fig. 185. Shaded Horizontal Cylinder

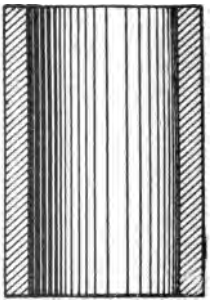


Fig. 186. Shaded Section of Hollow Cylinder

outside elements heavier as well as closer together, as shown in Figs. 184 to 190. Concavity is shown in the same manner, the

heavy shading always appearing on the left to indicate the deeper shadow, Figs. 186 and 188.

Fig. 184 is a cylinder showing the heaviest shade at the right, a method often used. Considerable practice is necessary to obtain good results; but in this, as in other portions of mechanical drawing, repetition is unavoidable. Fig. 185 represents a cylinder in a hori-

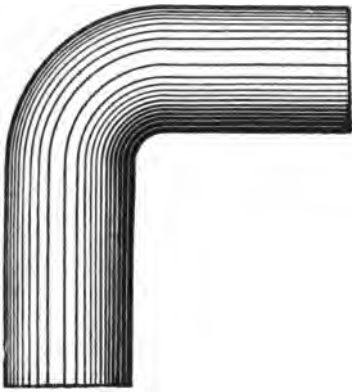


Fig. 187. Shaded Elbow Joint

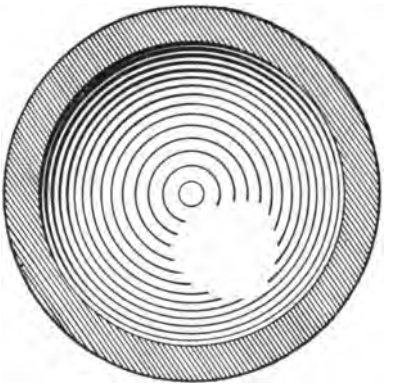


Fig. 188. Shaded Section of Hollow Sphere

zontal position, and Fig. 186 represents a section of a hollow vertical cylinder. Figs. 187 to 190 give other examples of familiar objects.

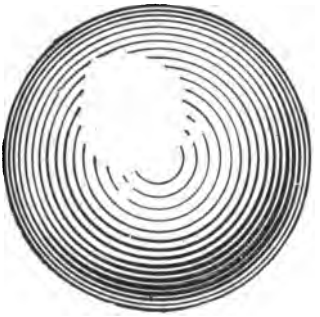


Fig. 189. Shaded Sphere

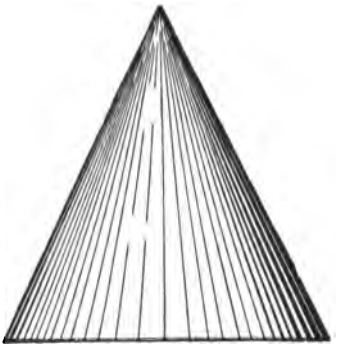


Fig. 190. Shaded Cone

In the elevation of the cone shown in Fig. 190 the shade lines should diminish in weight as they approach the apex. Unless this is done it will be difficult to avoid the formation of a blot at that point.

LETTERING

Types of Lettering. In the early part of this course, the inclined Gothic letter was described, and the alphabet given. The Roman, Gothic, and block letters are perhaps the most used for titles. These letters, being of comparatively large size, are generally made mechanically; that is, drawing instruments are used in their construction. In order that the letters may appear of the same height, some of them, owing to their shape, must be made a little higher than the others. This is the case with the letters curved at the top and bottom, such as C, O, S, etc., as shown somewhat exaggerated in Fig. 191. Also, the letter A should extend a little above, and V a little below, the guide lines, because if made of the same height as the others they will appear shorter. This is true of all capitals, whether of Roman, Gothic, or other alphabets. In the block letter, however, they are frequently all of the same size.

Size of Letters. There is no absolute size or proportion of letters, as the dimensions are regulated by the amount of space in which the letters are to be placed, the size of the drawing, the effect desired, etc. In some cases letters are made so that the height is greater than the width, and sometimes the reverse; sometimes the height and width are the same. This last proportion is the most common. Certain relations of width, however, should be observed. Thus, in whatever style of alphabet used, the W should be the widest letter; J the narrowest, M and T the next widest to W, then A and B. The other letters are of about the same width.

Vertical Gothic. In the vertical Gothic alphabet, the average height is that of B, D, E, F, etc., and the additional height of the curved letters and of the A and V is very slight. The horizontal cross lines of such letters as E, F, H, etc., are slightly above the center; those of A, G, and P slightly below.

Inclined Gothic. For the inclined letters, Fig. 192, 60 degrees is a convenient angle, although they may be at any other angle suited to the convenience or fancy of the draftsman. Many draftsmen use an angle of about 70 degrees.

Roman. The letters of the Roman alphabet, whether vertical, Fig. 193, or inclined, Fig. 194, are quite ornamental in effect if well made, the inclined Roman being a particularly attractive letter,

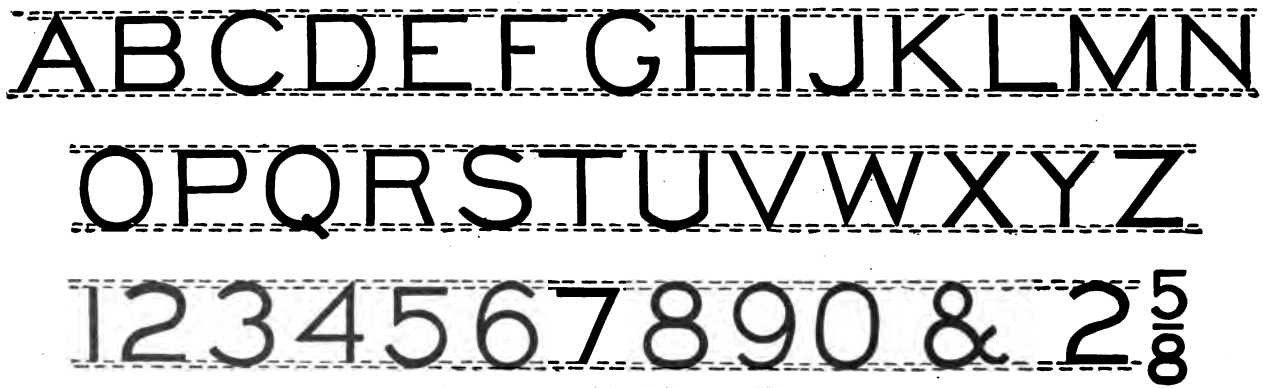


Fig. 191. Vertical Gothic Letters and Figures

Fig. 192. Inclined Gothic Letters and Figures

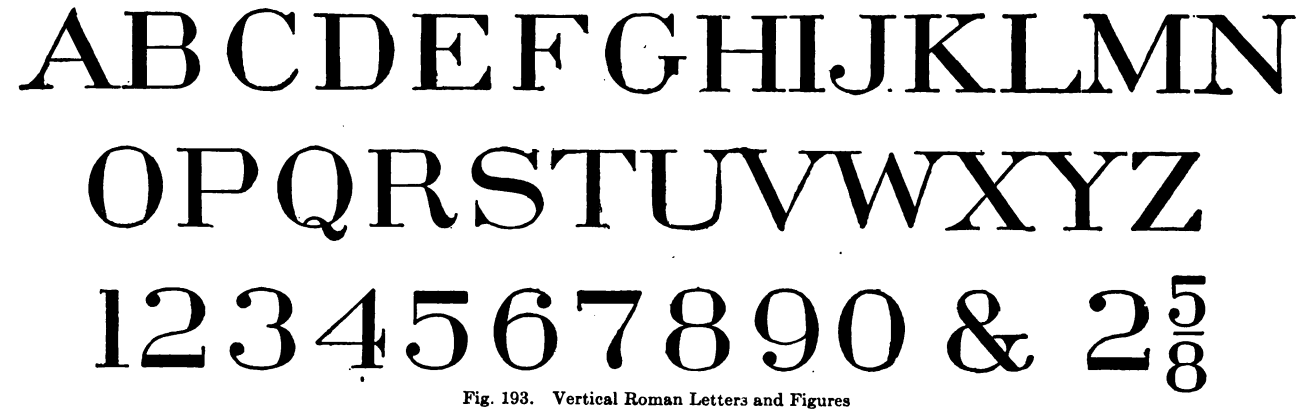


Fig. 193. Vertical Roman Letters and Figures

Fig. 194. Inclined Roman Letters and Figures

although rather difficult to make. The block letter, Fig. 195, is made on the same general plan as the Gothic, but much heavier. Small squares are taken as the unit of measurement, as shown. The use of this letter is not advocated for general work, although

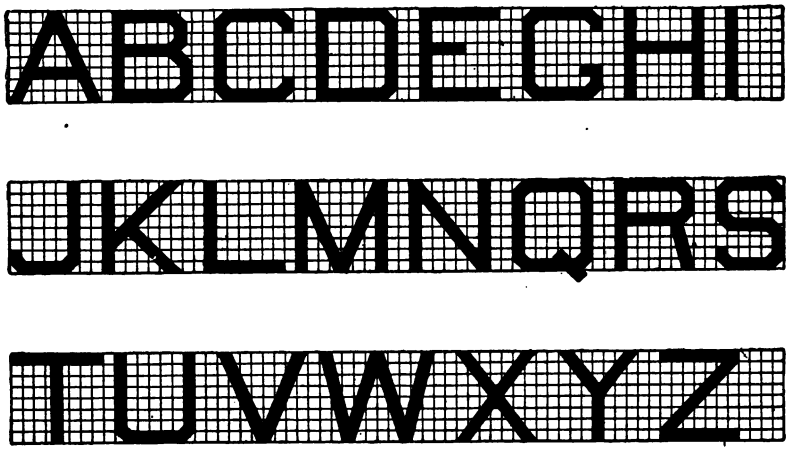


Fig. 195. Block Letters

if made merely in outline the effect is pleasing. The styles of numbers, corresponding with the alphabets of capitals given here, are also inserted. When a fraction, such as $2\frac{5}{8}$ is to be made, the proportion should be about as shown. For small letters, usually

Fig. 196. Vertical Gothic Lower-Case Letters

called lower-case letters, the height may be made about two-thirds that of the capitals. This proportion, however, varies in special cases.

Lower-Case Letters. The principal lower-case letters in general use among draftsmen are shown in Figs. 196, 197, 198, and 199.

The Gothic letters shown in Figs 196 and 197 are much easier to make than the Roman letters in Figs. 198 and 199. These letters,

Fig. 197. Inclined Gothic Lower-Case Letters

however, do not give as finished an appearance as the Roman. As has already been stated in Mechanical Drawing, Part I, the inclined letter is easier to make because slight errors are not so apparent.

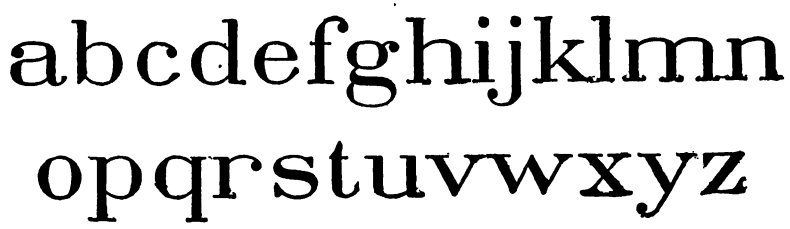


Fig. 198. Vertical Roman Lower-Case Letters

Spacing. One of the most important points to be remembered in lettering is the spacing. If the letters are finely executed but

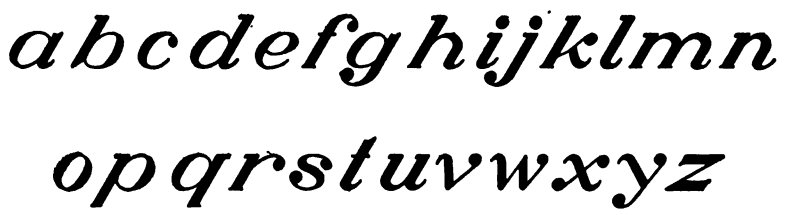


Fig. 199. Inclined Roman Lower-Case Letters

poorly spaced, the effect is not good. To space letters correctly and rapidly requires considerable experience; and rules are of little

Fig. 200. Sample of Letter Spacing

value on account of the many combinations in which letters are found. A few directions, however, may be found helpful. For

instance, take the word TECHNICALITY, Fig. 200. If all the spaces were made equal, the space between the L and the I would appear to be too great, and the same would apply to the space between the I and the T. The space between the H and the N and that between the N and the I would be insufficient. Usually, when the vertical side of one letter is followed by the vertical side of another, as in H E, H B, I R, etc., the maximum space should be allowed. Where T and A come together the least space is given, for in this case the top of the T frequently extends over the bottom of the A. In general, the spacing should be such that a uniform appearance is obtained. For the distances between words in a sentence, a space of about 1½ the width of the average letter may be used. The space, however, depends largely upon the desired effect.

Penciling before Inking. For large titles, such as those placed on charts, maps, and some large working drawings, the letters should be penciled before inking. If the height is made equal to the width, considerable time and labor will be saved in laying out the work. This is especially true with such Gothic letters as O, Q, C, etc., as these letters may then be made with compasses. If the letters are of sufficient size, the outlines may be drawn with the ruling pen or compasses, and the spaces between filled in with a fine brush.

Titles for Working Drawings. The titles for working drawings are generally placed in the lower right-hand corner. Usually a draftsman has his choice of letters, mainly because after he has become used to making one style he can do it rapidly and accurately. However, in some drafting rooms the head draftsman decides what lettering should be used. In making these titles, the different alphabets are selected to give the best results without spending too much time. In most work the letters are made in straight lines, although frequently a portion of the title is found lettered on an arc of a circle.

In Fig. 201 is shown a title having the words CONNECTING ROD lettered on an arc of a circle. To do this work requires considerable patience and practice. First, draw the vertical center line as shown at *C* in Fig. 201, then, draw horizontal lines for the horizontal letters. The radii of the arcs depend upon the general

arrangement of the entire title, and this is a matter of taste. The difference between the arcs should equal the height of the letters. After the arc is drawn, the letters should be sketched in pencil to find their approximate positions. After this is done, draw radial lines from the center of the letters to the center of the arcs. These

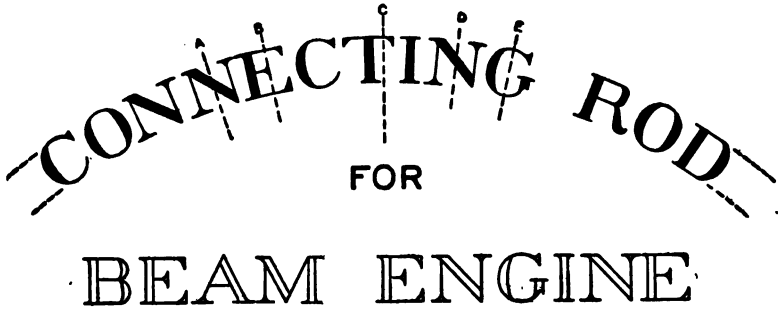


Fig. 201. Sample Title

lines will be the centers of the letters, as shown at *A*, *B*, *D*, and *E*. The vertical lines of the letters should not radiate from the center of the arc, but should be parallel to the center lines already drawn; otherwise the letters will appear distorted. Thus, in the letter *N*

Fig. 202. Sample Title

the two verticals are parallel to the line *A*. The same applies to the other letters in the alphabet. In making the curved letters such as O and C, the centers of the arcs will fall upon these center lines; and if the compasses are used, the lettering is a comparatively simple matter. In Fig. 202 is shown another title in which all the letters are in horizontal lines.

PLATES

Plates IX to XV, inclusive, are to be drawn by the student for practice in applying the principles of orthographic projection, intersections and developments, isometric and oblique projection, and for practice in lettering. These plates are to be made 11 inches by 15 inches outside, with a margin of ½ inch, making the clear space for the drawing 10 inches by 14 inches. All the plates are to be inked.

PLATE IX

After laying out the border line on the plate, draw a ground line horizontally across the upper part of the plate, 3 inches below the upper border line. On this ground line six figures, spaced as regularly as possible, are to be drawn, as follows:

1. Draw the projections of a line $1\frac{1}{2}$ inches long which is parallel to both planes, 1 inch above the horizontal, and $\frac{3}{4}$ inch from the vertical.

2. Draw the plan and elevation of a line $1\frac{1}{2}$ inches long which is perpendicular to the horizontal plane and 1 inch from the vertical. Lower end of line is $\frac{1}{2}$ inch above H.

3. Draw the projections of two intersecting lines: one 2 inches long to be parallel to both planes, 1 inch above H, and $\frac{3}{4}$ inch from the vertical; and the other to be oblique to both planes and of any desired length.

NOTE. The idea for drawing the three figures referred to in 1, 2, and 3 can be obtained from Figs. 104 and 105 in this textbook.

4. Find the true length of a line whose vertical projection is $1\frac{1}{4}$ inches long, the left end on the ground line and inclined at 30 degrees. The horizontal projection has the left end $\frac{1}{2}$ inch from V, and the right $1\frac{1}{2}$ inches from V.

5. Find the true length of a line whose horizontal projection is 1 inch long, whose right end is $\frac{1}{2}$ inch above the ground line, and inclined at 60 degrees. The vertical projection has the right end $\frac{1}{2}$ inch below the ground line and the left 1 inch.

6. Find the true length of a line whose projections are perpendicular to the ground line. The horizontal projection is 2 inches long, the bottom end being $\frac{1}{2}$ inch above the ground line. The vertical projection is 1 inch long, the top end being $\frac{1}{2}$ inch below the ground line.

NOTE. The idea for drawing the figures referred to in 4, 5, and 6 can be obtained from Figs. 120 and 121 in this textbook.

In the lower half of the plate, four more figures are to be drawn, also spaced as regularly as possible, so that the finished plate will be well balanced:

7. Draw the plan and elevation of a round bolt with a square head. The head is to be uppermost in the elevation. The bolt

is to be 2 inches long and $\frac{1}{2}$ inch in diameter. The head is to be $\frac{3}{4}$ inch square, $\frac{1}{4}$ inch thick, and have one face parallel to V.

8. Draw the plan and elevation of a round bolt having the same dimensions as in 7, but with a hexagonal head; the head to be uppermost in the elevation, and to be $\frac{3}{4}$ inch in width between faces $\frac{1}{4}$ inch thick, and to have one face parallel to V.

9. Draw the plan and elevation of a cylinder, perpendicular to H, 2 inches high and 2 inches in diameter, with a hole 1 inch in diameter passing vertically completely through it.

10. Draw the plan, elevation, and end view of a rectangular block 6 inches long, 2 inches wide, and 1 inch thick. One of the 2 inch by 6 inch sides is to be parallel to H. The right end is turned down to a cylindrical form 1 inch in length and 1 inch in diameter.

In all the work of this plate, construction lines should be fine dotted lines and should be inked in.

PLATE X

The figures on the reproduced Plate X on the opposite page give the outline of the work that is to be completed by the student. The dimensions given on this plate are to be used in working out the problem, but are not to appear on the finished plate. The first figure shown represents a rectangular block with a rectangular hole cut through from front to back. The other two figures represent the same block in different positions. In drawing these figures, the student must put in all construction lines in order to show how each view is obtained.

After completing the construction of the views as shown, the projection of four holes, $\frac{1}{2}$ inch in diameter each, are to be drawn. One hole passes through the center of each end, and one hole through the center of each side. All these small holes pass completely through to the large hole in the center of the block. Next, put two square projecting pieces on the front face of the block, on the center line, $\frac{1}{2}$ inch from each end. These projecting pieces are to be $\frac{1}{2}$ inch square and $\frac{1}{4}$ inch deep.

The projections of the four small holes and two projecting pieces are to be drawn in all views in the conventional manner, and the necessary construction lines for this work are to be left on the plate and inked in.

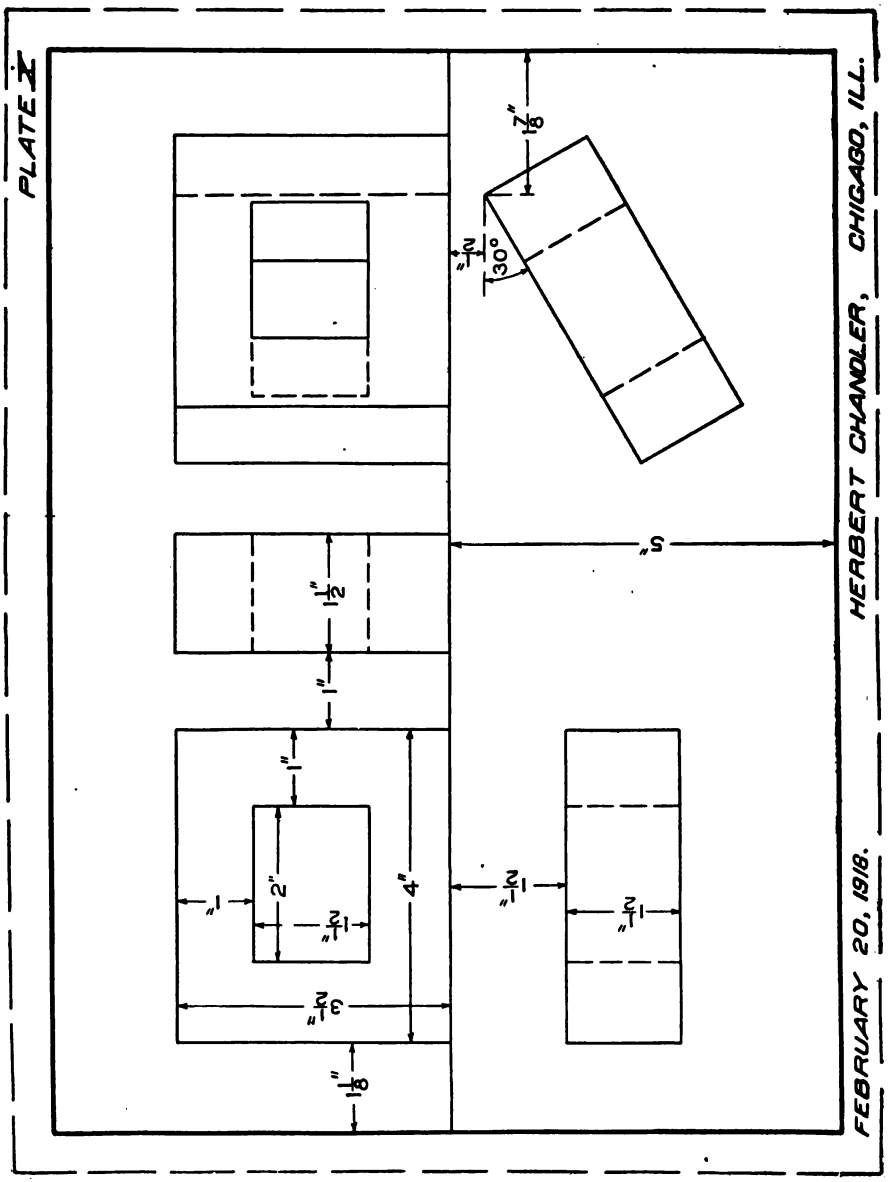


PLATE X
HERBERT CHANDLER, CHICAGO, ILL.
FEBRUARY 20, 1918.
1⅞"
½"
30°
5"
1½"
1"
1"
2"
1"
4"
1"
1"
1"
3½"
⅛"

PLATE XI

At the left of this plate draw the plan, front and side views of the monument shown in elevation on reproduced Plate XI on the opposite page. The total height of the monument is 6 inches. All four sides are alike except that the width of the base is 2 inches and the depth $1\frac{1}{2}$ inches, and the width of the body of the monument is $1\frac{1}{2}$ inches and the depth 1 inch. The height of the base is $\frac{1}{2}$ inch, of body 3 inches, and the faces just above the base have a slope of 60 degrees with the horizontal. The width of the ridge at the extreme top of the monument is 1 inch.

The figures for the right side of the plate represent a pentagonal pyramid in three positions. The first position is the pyramid with the axis vertical. The height of the pyramid is $2\frac{1}{2}$ inches, and the diameter of the circle circumscribed about the base $2\frac{1}{2}$ inches. The center of the circle is 6 inches from the left margin and $2\frac{1}{2}$ inches below the upper border line. Spaces between figures to be $\frac{1}{2}$ inch.

In the second figure the pyramid has been revolved about the right-hand corner of the base as an axis, through an angle of 15 degrees. The axis of the pyramid, shown dot and dash, is therefore at 75 degrees. The method of obtaining 75 degrees and 15 degrees with the triangles was shown in Part I. From the way in which the pyramid has been revolved, all angles with V must remain the same as in the first position; hence the vertical projection will be the same shape and size as before. All points of the pyramid remain the same distance from V. The points on the plan are found on T-square lines through the corners of the first plan and directly above the points in elevation. In the third position the pyramid has been swung around, about a vertical line through the apex as axis, through 30 degrees. The angle with the horizontal plane remains the same; consequently the plan is the same size and shape as in the second position, but at a different angle. Heights of all points of the pyramid have not changed this time, and hence are projected across from the second elevation.

PLATE XII

DEVELOPMENTS

On this plate draw the developments of a truncated octagonal prism, and of a truncated pyramid having a square base. The

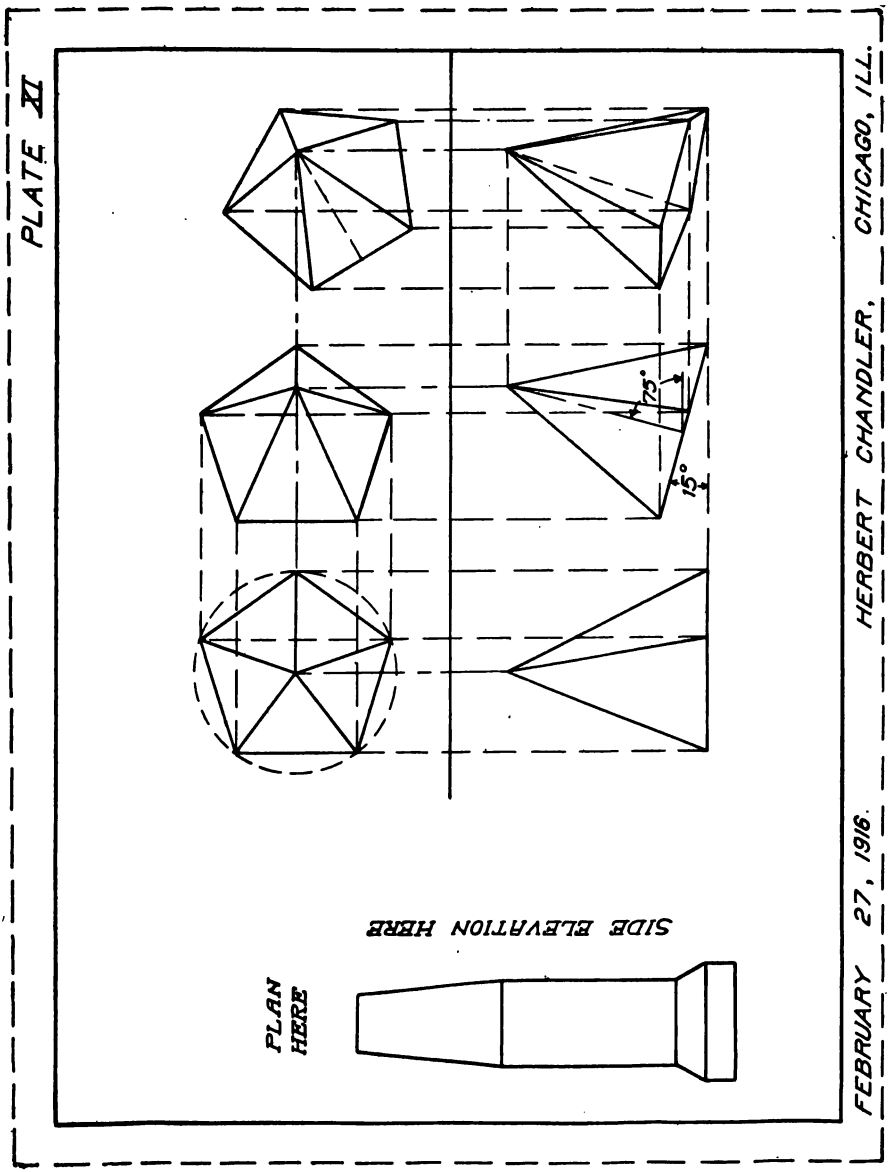


PLATE XI
75°
15°
SIDE ELEVATION HERE
PLAN HERE
FEBRUARY 27, 1916. HERBERT CHANDLER, CHICAGO, ILL.

arrangement on the plate is left to the student; but it is suggested that the truncated prism and its development be placed at the left,

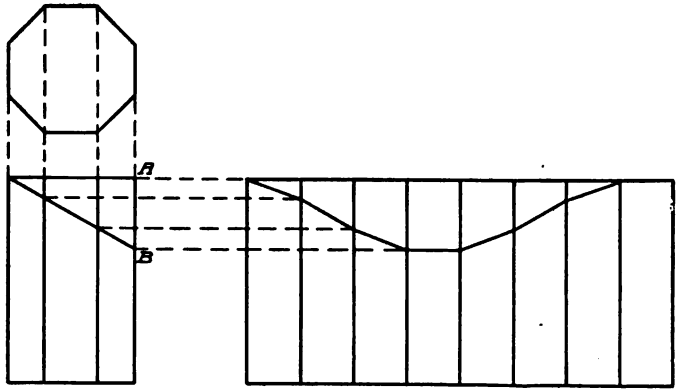


Fig. 203. Plan, Elevation, and Development of an Octagonal Prism

and that the development of the truncated pyramid be placed under the development of the prism; the truncated pyramid may be placed at the right.

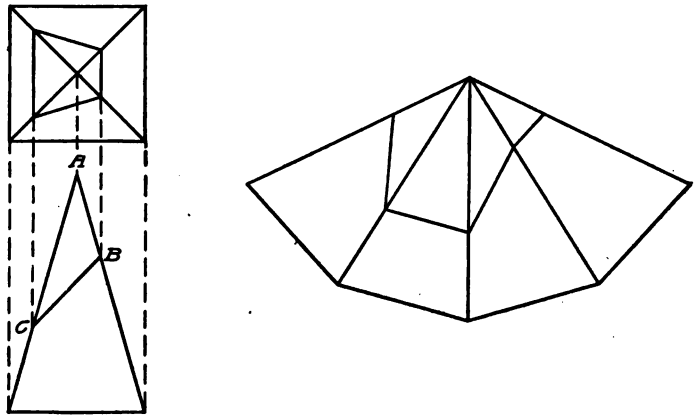


Fig. 204. Plan, Elevation, and Development of a Square Pyramid and Cutting Plane

The prism and its development are shown in Fig. 203. The prism is 3 inches high, and the base is inscribed in a circle $2\frac{1}{8}$ inches in diameter. The plane forming the truncated prism is passed as indicated, the distance AB being 1 inch. Ink a sufficient number of construction lines to show clearly the method of finding the development.

The pyramid and its development are shown in Fig. 204. Each side of the square base is 2 inches, and the altitude is $3\frac{1}{2}$ inches. The plane forming the truncated pyramid is passed in such a position that AB equals $1\frac{3}{8}$ inches, and AC equals $2\frac{1}{2}$ inches. In this figure the development may be drawn in any convenient position, but in the case of the prism it is better to draw the development as shown. Indicate clearly the construction by inking the construction lines.

PLATE XIII

ISOMETRIC AND OBLIQUE PROJECTION

In the upper left quarter of this plate draw the isometric projection of the block which is shown on reproduced Plate X, page 137, taking the dimensions from your finished Plate X. The idea for this problem can be obtained by referring to Fig. 158 in this textbook.

In the upper right quarter of this plate draw the isometric projections of the two round bolts described in 7 and 8 of Plate IX, taking dimensions from your finished Plate IX.

In the lower half of this plate draw, at 45 degrees, the oblique projections of the cylinder and the rectangular block, described in 9 and 10 of Plate IX, taking dimensions from your finished Plate IX. The idea for this can be obtained by referring to Figs. 175 and 179 in this textbook.

PLATE XIV

FREE-HAND LETTERING

On account of the importance of free-hand lettering, the student should practice it at every opportunity. For additional practice, and to show the improvement made since completing Part I, lay out Plate XIV in the same manner as Plate I, and letter all four rectangles. Use the same letters and words as in the lower right-hand rectangle of Plate I.

PLATE XV

LETTERING

First lay out Plate XV in the same manner as previous plates. After drawing the vertical center line, draw light pencil lines as

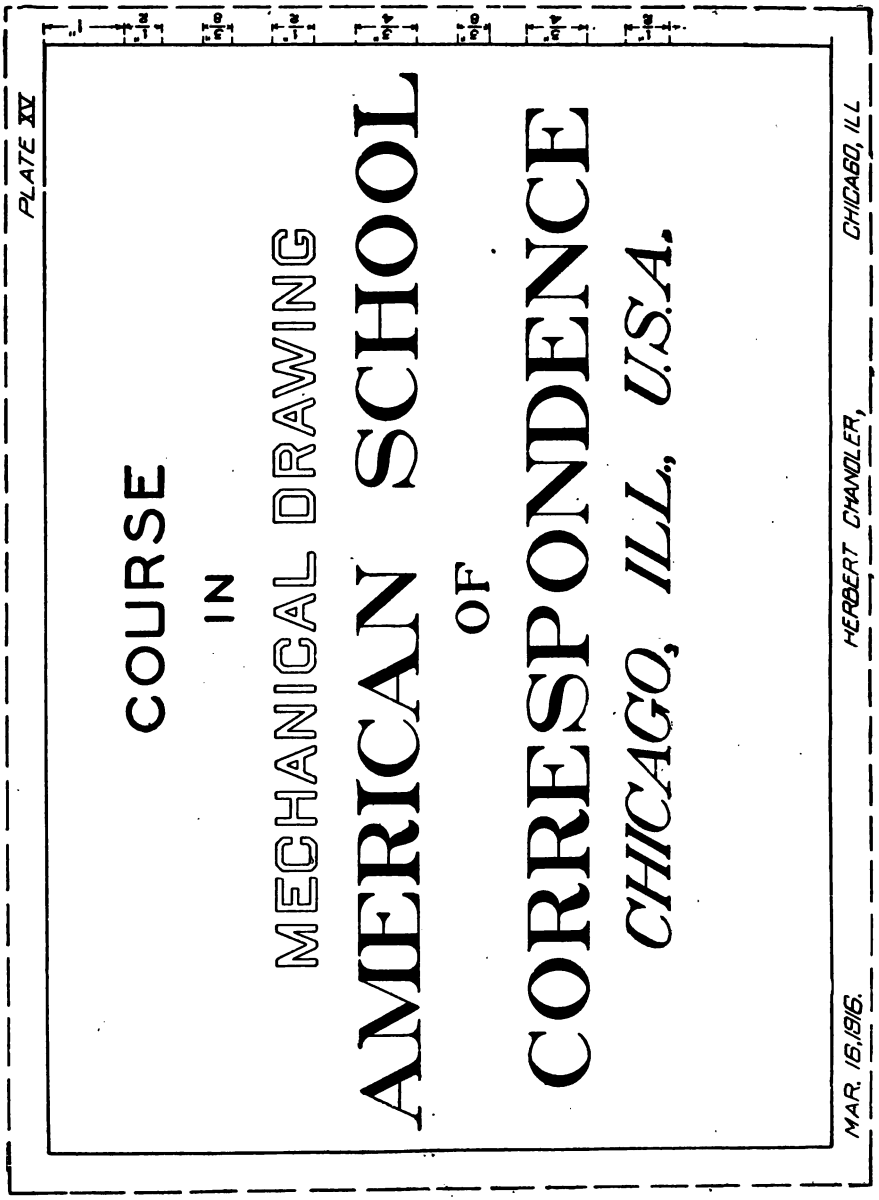


PLATE XV
COURSE
IN
MECHANICAL DRAWING
OF
AMERICAN SCHOOL
CORRESPONDENCE
CHICAGO, ILL., U.S.A.
MAR. 16, 1916.
HERBERT CHANDLER,
CHICAGO, ILL.

guide lines for the letters. The height of each line of letters is shown on the reproduced plate. The distance between the letters should be ½ inch in every case. The spacing of the letters is left to the student. He may facilitate his work by lettering the words on a separate piece of paper, and finding the center by measurement or by doubling the paper into two equal parts. The styles of letters shown on the reproduced plate should be used.

FRAGMENTS FROM ROMAN TEMPLE AT CORI, ITALY
One of the most interesting examples of architectural rendering in existence
Original drawing by Emanuel Brune
Reproduced by permission of Massachusetts Institute of Technology

ARCHITECTURAL DRAWING.

PART I.

Instruments and Materials. The study of mechanical drawing has acquainted the student with the use of the ordinary drawing instruments and materials. Those required for architectural work are substantially the same.

Pencils. Soft pencils are used; a draftsman cannot have advanced far in ability before becoming familiar with the B B pencil, which will draw any line, from the finest to the coarsest, and give the greatest freedom for all kinds of work, from sketching to full-size details.

In architects' offices it is an almost invariable rule for the new-fledged student and young draftsman to use hard pencils—"nails," as they are called by more experienced men. A soft pencil gives a much more agreeable expression of ideas on paper than a hard pencil; the latter should be reserved for mechanical work. The draftsman must not allow himself to become less accurate as he gains greater freedom, and the use of a soft pencil gives no excuse for a careless or slovenly drawing. H H, F and B B will be found the most useful grades. For laying out work, H H is often used.

Erasers. The noted architect, H. H. Richardson, said that "an eraser is a draftsman's best friend." For work on detail paper, a firm rubber is best, but a soft rubber is most serviceable for removing ordinary pencil marks from all kinds of paper, including the thin tracing papers, without injury to the surface. It will be found that the eraser can be frequently used in studying outlines, and it is the custom for rapid draftsmen to let the pencil lines run where they will, trusting to the eraser to make the outline true. A large size ink eraser will be found easier on the hands than a small one. In making erasures a typewriter's shield of metal with different sizes

For some of the text and several of the illustrations in ARCHITECTURAL DRAWING the French work, Eléments et Théorie de l'Architecture, Vol. I., by Guadet, has been drawn on freely. The four volumes of this work by Guadet cannot be too highly recommended. Even those not familiar with the French language will find it an excellent reference work on account of the numerous useful illustrations it contains.

of openings, corresponding to the erasures to be made, called in draftsman's parlance, the "office goat," is useful. Holes can be cut in cardboard or detail paper for this purpose.

Set of Instruments. Good instruments are advisable, as it is hard enough to make good drawings, even with the best. Compasses with pencil and pen points and extension legs; large and small dividers, bow-pen and bow-pencil, and two ruling pens, form the usual equipment of the architectural draftsman's instrument case. Besides these a simple form of proportional dividers will be found very useful, especially in changing drawings from one scale to another, and also when it is desired to translate a rough sketch into a definite scale, preserving the proportions of the sketch. A small protractor will be sufficient for the rare occasions when an architect lays off angles to a given number of degrees.

Beam compasses are useful, though many offices have only long straight edges and carpenters' clamps for this purpose. Sometimes a taut string will serve the purpose where perfect accuracy is not required, or two points on a straight edge may be taken, one point being held with one hand, while a curve is struck from another point by a pencil held in the other hand.

Drawing Boards. It is necessary to have two drawing boards, one a "Double Elephant" size, 28 × 42 inches, to accommodate paper of a size called "Double Elephant," which is 27 × 40 inches, thus allowing ½ inch at the sides and an inch at the ends; the other board 23 × 32 inches, to accommodate the size of paper called "Imperial," which is 22 × 30 inches. It will be found convenient also to have a small "Half Imperial" board 23 × 16 inches in size. These boards should have a straight grained cleat at each end, or should be entirely surrounded with a framework of hard wood, having soft wood in the center. Cherry makes a good hard wood for the frames or ends, and pine or white wood for center. In many offices the boards are made entirely of pine or white wood, but it will be found preferable to have better made boards, and to take good care of them, keeping them square. If adjacent sides of the board make a true right-angle, the T-square can be used on these two sides, which is an advantage in drawing long lines. When the boards have cleats at the ends only, however, it is always necessary to use the T-square from the left-hand end only.

Triangles and T-Squares. There are T-squares to correspond to the size of the boards. They are usually made of straight, fine grained hard wood. The simplest form of fixed T-square will be found the most satisfactory for general office use. As even the best are apt to vary, it is a good idea to number every T-square in the office and note the number on commencing a drawing. If, however, the T-square is changed, and the new square does not line up with the old work, a thumb tack in the edge of the head next the drawing board may be used to bring the blade into line, as shown in Fig. 1. The drawing edge (upper edge) of a T-square should never be used as a straight edge for paper cutting.

Two triangles are required, one 30 degrees to 60 degrees, and one of 45 degrees. Triangles are made of wood, hard rubber or celluloid.

Materials for Wash-Drawings. For tinting, a nest of tinting saucers, brushes, a soft sponge, large blotters, a stick of India ink, a slate slab for grinding it, a half cake of carmine and a half tube of Prussian blue will make a good beginning.

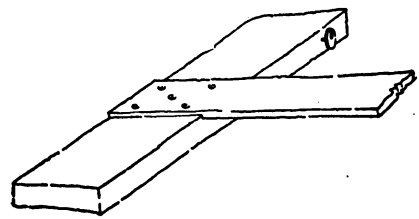


Fig. 1. T-Square with Thumb Tack.

Paper. Paper comes in certain conventional sizes. "Whatman's paper" is most easily obtained in two sizes, the "Imperial," 22 × 30 inches, and "Double Elephant," 27 × 40 inches, and is a useful paper for all-around architectural work, being good for pencilling, inking in, and wash drawings; colors can be laid on it even after erasures have been made. The Whatman "hot-pressed" paper has a smooth surface and is generally used for fine pencil or ink drawings. The Whatman "cold-pressed" paper has a rough surface and good texture, and is useful for all-around work.

Tinted Papers. Gray or other colored papers are frequently employed, pencil or pen and ink being used for the lines and shadows, and chalk or Chinese white for the high lights. Pastels and water colors are used on special colored papers; "scratch papers" are those on which white is obtained by scratching through the colored surface of the paper. Some of these papers, including buff or manila detail paper, have already been fully described under the subject of mechan-

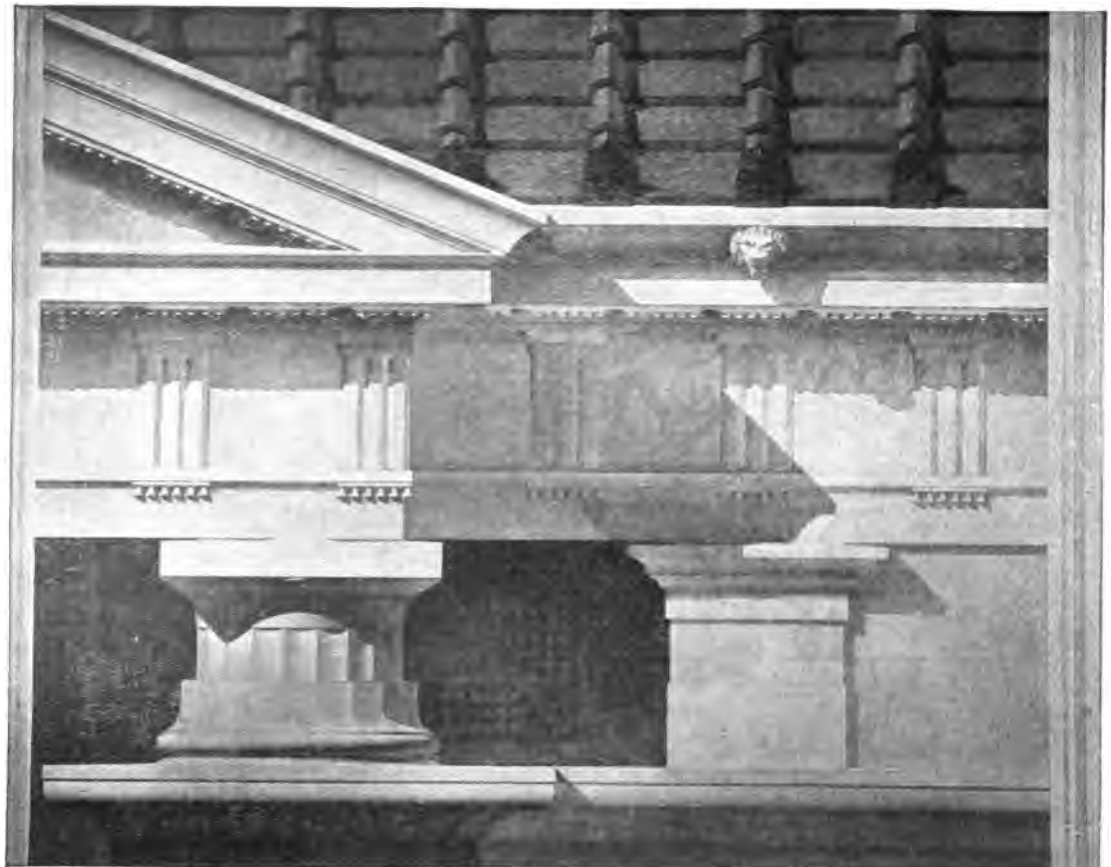
ical drawing. The process of stretching paper is also there described.

Tracing Paper. In architectural work a great deal of tracing paper is used. A cheap manila tracing paper is convenient for rough preliminary studies not intended to be preserved. "Alba," a white tough tracing paper, and "Economy," a cheaper form, are very good for pencil sketching and also for careful pencil drawings. Rowney's English tracing paper is very transparent, is good for accurate pencilling, and takes color, but becomes brittle with age; it is, however, the best paper for careful studies of architectural work. Bond paper which comes in sheets 20 × 28 inches, is very useful for working drawings of small frame houses, as the drawing can be inked-in and blue prints taken directly from this paper without the necessity of tracing.

Some offices make many of their details in black pencil on this paper and where work on different houses is similar, let blue prints of these details serve for each new building.

Tracing Cloth. Tracing cloth is used for important work where the tracing will be roughly used or where changes are likely to be made in the drawing. In drawing on tracing cloth, there are three ways of making the ink flow well: (1) The most common is to rub powdered chalk over the surface, dusting off the superfluous chalk; (2) Benzine applied with a towel will clean the cloth; (3) Oxgall, a preparation obtainable at any artists' materials store, may be mixed with the ink. Sometimes pencil drawings are made directly on the cloth, and after inking-in benzine is used to remove all pencil marks. As a rule, the rough side of the tracing cloth is used, but some draftsmen prefer to ink-in on the smooth side, thinking they can make a cleaner line, and then turn the cloth over to color the drawing on the rough side with water colors or crayons.

Scales. Scales for architectural work are like those used for mechanical drawing, one-quarter inch to the foot for working drawings, and three-quarter inch to the foot for details, being the customary scales used in American offices, though some offices use one-eighth inch to the foot, with one-half inch to the foot for details—the custom usually followed in England. It is customary to make full-size details of mouldings and of special constructive parts. Three-sixteenths inch to the foot is sometimes useful as a scale drawing, or



DETAIL OF GREEK DORIC ORDER
An example of conventional shadows and rendering
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in laying out stairs in section, as will be described later. This scale is also frequently used for exhibition drawings. One and one-half inch to the foot, one inch to the foot, and three inches to the foot, are also used. For the scale of three inches to the foot, the ordinary quarter-inch scale may be read as inches instead of feet, as one-quarter inch is one-twelfth of three inches. The three-quarter inch scale is the favorite among carpenters for the reason that the ordinary two-foot rule can be used on the drawings; as there are twelve-sixteenths of an inch in every three-quarters of an inch, each sixteenth of an inch on the rule represents one inch actual measurement. The inch scale is very popular for drawing mantels, interior finish, etc., where the total dimensions can be read directly from the two-foot rule, each inch being equal to the foot full size.

The accompanying illustration of an architect's scale, Fig. 2, shows the usual divisions on a scale for ordinary architectural work.

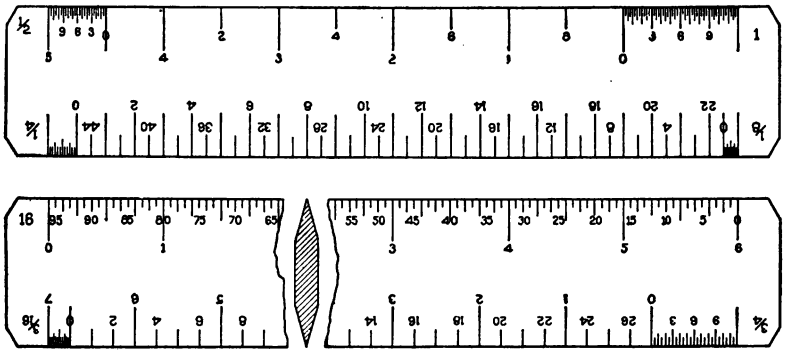


Fig. 2. Architects' Scale.

A six-inch scale of this size is very convenient for ordinary measurements and a similar one eighteen inches or two feet long is useful for laying out larger work. This scale gives the full-size measurements in inches divided into sixteenths with the scales of sixteenths reading in the reverse order from zero up, so that the number can be read directly from a sixteenth scale or doubled for a thirty-second inch scale. The common quarter-inch and eighth-inch scales are given, as well as the half-inch and one-inch scales. The useful three-quarter inch scale is given with the three-sixteenths scale in reverse order.

The accompanying sketch, Fig. 3, shows how a scale may be used in laying out staircases in plan and section much more rapidly

than is usual in architects' offices. The sketch shows the plan and section of a staircase at a scale of one-quarter of an inch to the foot, the staircase to be three feet six inches wide. The section shows that the floors are nine feet six inches between finished surfaces. As it is desirable to economize space, the stairs are to be laid out with about seven and one-half inches rise and eleven inches tread. Dividing nine feet six inches by seven and one-half, we find that fifteen

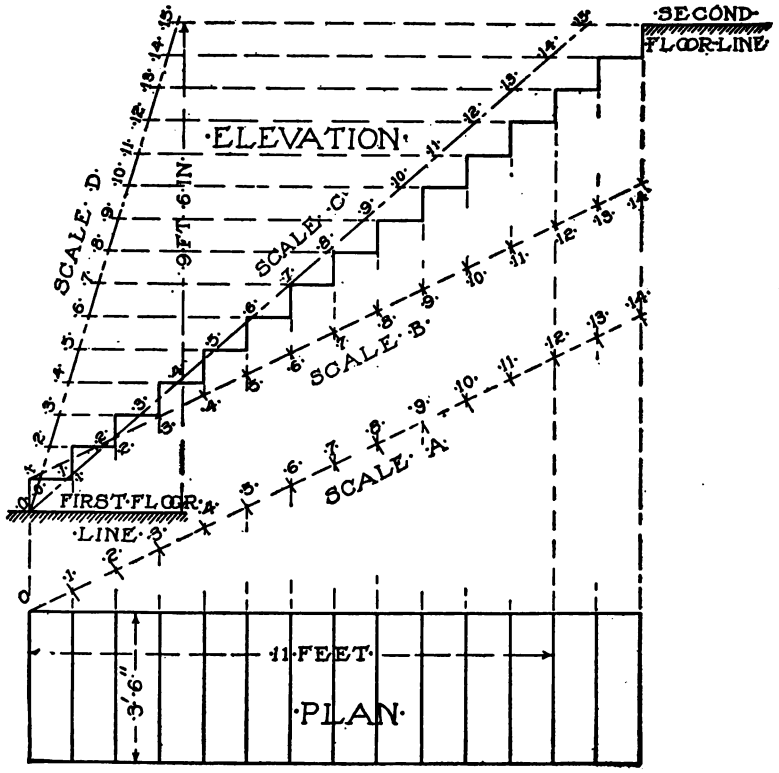


Fig. 3. Use of Scales in Laying out Stairs.

risers will give us slightly over seven and one-half inches. To lay out fourteen treads—which locate the fifteen risers including the first and last—instead of spacing over fourteen treads, start from the first riser, lay off parallel to run of stairs in plan eleven feet on the quarter-inch scale; then draw a line perpendicular to the run of the stairs. Tip the scale until the zero coincides with the first tread and twelve

coincides with the line just drawn. Each division of the quarter scale marked off as a scale of proportional parts will give us a series of points through which we can draw parallel lines which will locate the risers eleven inches apart. If it is found that the stairs do not arrive at the point desired, the scale can be tipped more or less and each tread decreased or increased. The same method can be followed for laying out the stairs in elevation.

LINE DRAWING.

Character of Line. The thickness of the line in drawing should be the same throughout its length, except occasionally in perspective rendering. The line may vary in different parts of the same drawing, and in different drawings, according to how much or how little detail is to be shown, but in every case the lines should be firm and clear. Those parts of an elevation which are nearest to the spectator should be drawn in heavier lines than the more distant parts. Thick lines generally tend to simplify the design. The outline of the curved mouldings, excepting those circular in section, should be drawn freehand, as they can be given more character in that way than if made with the compass.

The compass should be used in such a way that the point will not make large holes in the paper. The arms of the compass should be bent so that the pencil point and needle point will be perpendicular to the paper. Pencil lines should be made without a heavy pressure so as not to dent the paper. The ruling pen should be held like the pencil and used very lightly, for if too much weight is put upon the pen, the paper will be cut, and if the pen is pressed too hard against the T-square the blades of the pen will be closed and the lines become weaker. It is also necessary that the ink should always flow freely from the drawing pen. It should be renewed frequently and the pen should be cleaned each time it is refilled. If the ink refuses to flow, it frequently can be started by touching the end of the pen to the moistened finger, capillary attraction immediately starting the ink to flow.

Ordinary writing ink should not be used with the drawing pen. After the drawing is inked in, the pencil lines can be erased. The student will eventually become accustomed to making the important lines with the pencil and putting in many of the lines of the drawing

immediately in ink, between limiting lines in pencil. But the draftsman should be very sure of himself and his drawing before using this method.

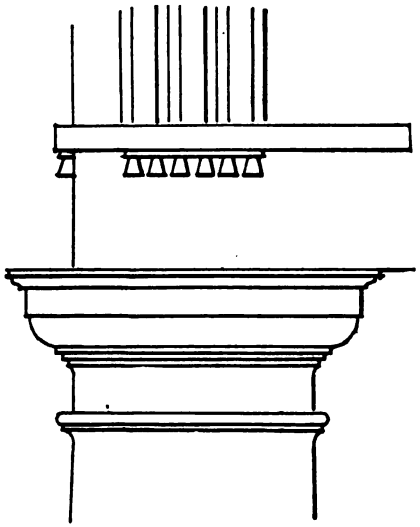


Fig. 4. Shade Lines.

Shade lining, or indicating shadows by making the lower and right-hand edges of projecting planes in elevation heavier, see Fig. 4, is used in architectural drawing, especially in illustrations for publication. In office work, when it is desired to show the shadows, the latter are generally laid in washes. The brilliancy of the architectural drawing shown in many recent examples, especially from New York offices, is much increased by strengthening the outline of projecting members and ornamental parts, by accenting certain points, and by carrying through only certain important lines of mouldings, and drawing other lines only a short distance. Finished lines coming down on to projecting surfaces may be stopped short just before reaching the surface, giving effect of high light on those surfaces, as shown in Fig. 4; and lines at outer angles may be carried slightly across each other, giving a firm intersection, instead of stopping just at the junction. For plans the same holds good, as is shown in Fig. 5.

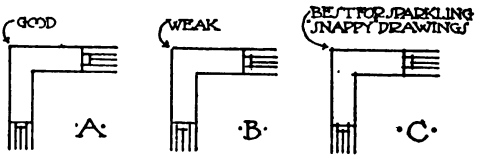
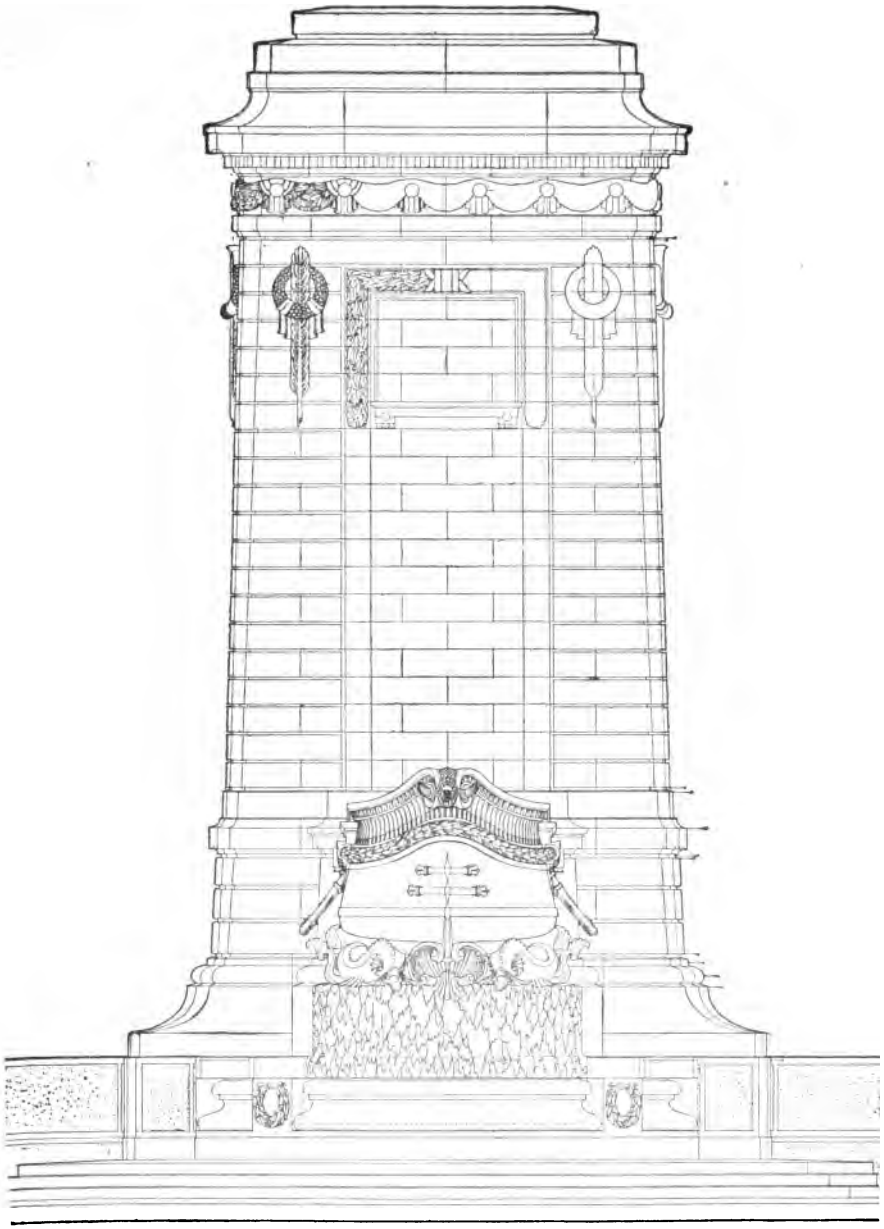


Fig. 5. Junctions of Lines.

In an elevation, the planes toward the front may be drawn with dark lines and those farther back with lighter lines. Joint lines in masonry and the lighter lines of carving should be drawn in ink which has been diluted with water. The design for the National Maine Monument, page 9, shows a good method of lining an architectural drawing.



First Prize Design. National Maine Monument.

H. Van Buren Magonigle, Architect.

Sometimes lines of different colors, as red to indicate brick, blue for stone, yellow for wood, etc., are used on working drawings to take the place of tinting.

DEFINITIONS.

Architectural drawing is geometric. If the student is making the drawing of a model, he should try to think how the author of the model laid it out, and how he, the student, would proceed if he had the opportunity to lay it out. He will find that the model is represented on paper by the different projections such as the plans, sections and elevations. These are laid out to a certain scale; that is to say, one-fourth inch to the foot, which means that one-fourth inch in the drawing represents one foot in the model; or one-eighth inch to the foot, etc.

Definition of Plan. A plan of a building is a section cut by a horizontal plane through the walls, supports, etc., at such a height so as to show the greatest number of peculiarities in construction, walls, doors, windows, supports, columns and pilasters, fireplaces, etc. It is possible to consider a plan as a horizontal impression that could be taken of the building in course of construction when it had arrived at a certain level in the height of a story. On the plan the construction is shown invariably by horizontal sections, but it is possible to project up all that is below and also to show what is above. In the first case the plan will show the architectural portions which project beyond the base of the walls or supports such as the base, steps, approaches, etc. In the other case it will show vaultings, ceilings, entablatures, cornices, etc. Sometimes it is desirable to show both—half of each—provided the parts shown are sufficiently interesting or necessary for explaining the entire scheme.

Definition of Section. The section is a plane cut through a building vertically, that is to say, it is the same thing perpendicularly that the plan is horizontally. This plane should be taken along the line of some main axis.

A single section rarely is sufficient to give all the interior of the building. It is necessary to have, as a rule, at least two, one a longitudinal section, perpendicular as a rule to the facade, and the other a transverse section, usually parallel to the facade. Very often a

small section of the front alone is made. This should preferably be called a profile of the front.

Definition of Elevations. The elevations of a building are the projections of the building on vertical planes parallel to the side of the building of which an elevation is desired. Except in the case of complete uniformity, it is necessary to have several elevations in order to show the complete exterior of a building, such as the principal facade, side elevations, and rear elevation.

THE IMPORTANCE OF AXES IN ARCHITECTURAL DRAWING.

The axis is the key of a design or of any composition. An axis in geometry is a line which separates into two equal parts any symmetrical plane figure, or the pole of a surface of revolution or of a regular solid, such as a rectangular prism with a regular base. In architecture the idea of the axis is greater than this. It is in reality a vertical plane through the whole building separating the building into two parts symmetrically, or in such a way that they balance one another.

Although the graphical representation is confined to a straight line, do not forget that it is not simply a line. Take for example a church; in drawing the plan, the axis of this plan will be a straight line separating it into two parts, but this line itself will be only the projection of the central vertical plane which is the axis of the whole building; and the keystones of the vault, the lights which drop from them, the center of the rose window, etc., are *in the axis* of the church. Notice besides this that the straight line which is the axis of the plan, and the line which is the axis of the front and rear facade, the line which is the axis of the transverse section—these lines are only the traces, all belonging to some axis plane, as it may be called, and this plane is the principal axis.

But there are other minor axes. Parallel to the main axis are the axes of the side arms and between these are the axes of the columns. Running transversely are the axes of the transept, those of each bay, the radiating axes of the chapels, etc.

In laying out the drawings of a church, for example, first place all of these different axes with the utmost accuracy. This method of laying out the drawings of a building by starting with the axes may

be best explained by examples. Let us commence by the study of a plan, that of a vestibule, in a public building; *e.g.*, the Hotel des Monnaies at Paris, Fig. 6.

After having drawn the axis 1, which is the principal axis of the building, it will be noticed that there are five bays of the central pavilion which are spaced equally. Of these draw first the extreme axes, 2 2; by dividing the space between axes 1 and 2 into equal parts, the intermediate axes 3 3, will be found. In this way the chances of error would be decreased, for if the axes were placed in the order 1, 3, 2, the possible error would be doubled. Now taking the portion to the right, draw first the extreme axis 4, then 5, and divide the space 4 5 into equal parts, which will give the axis 6.

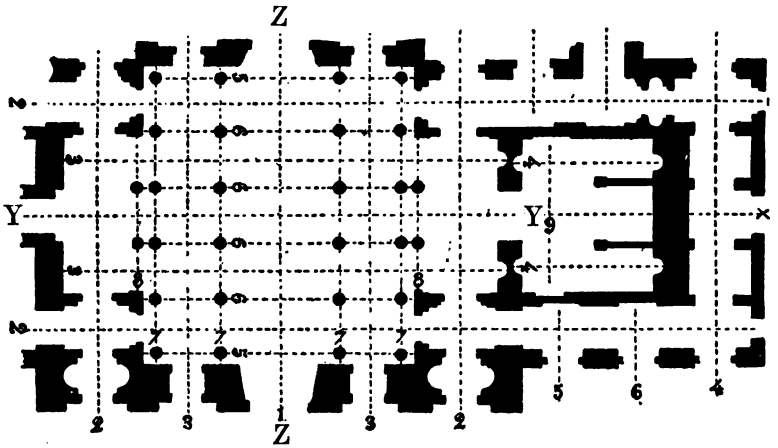
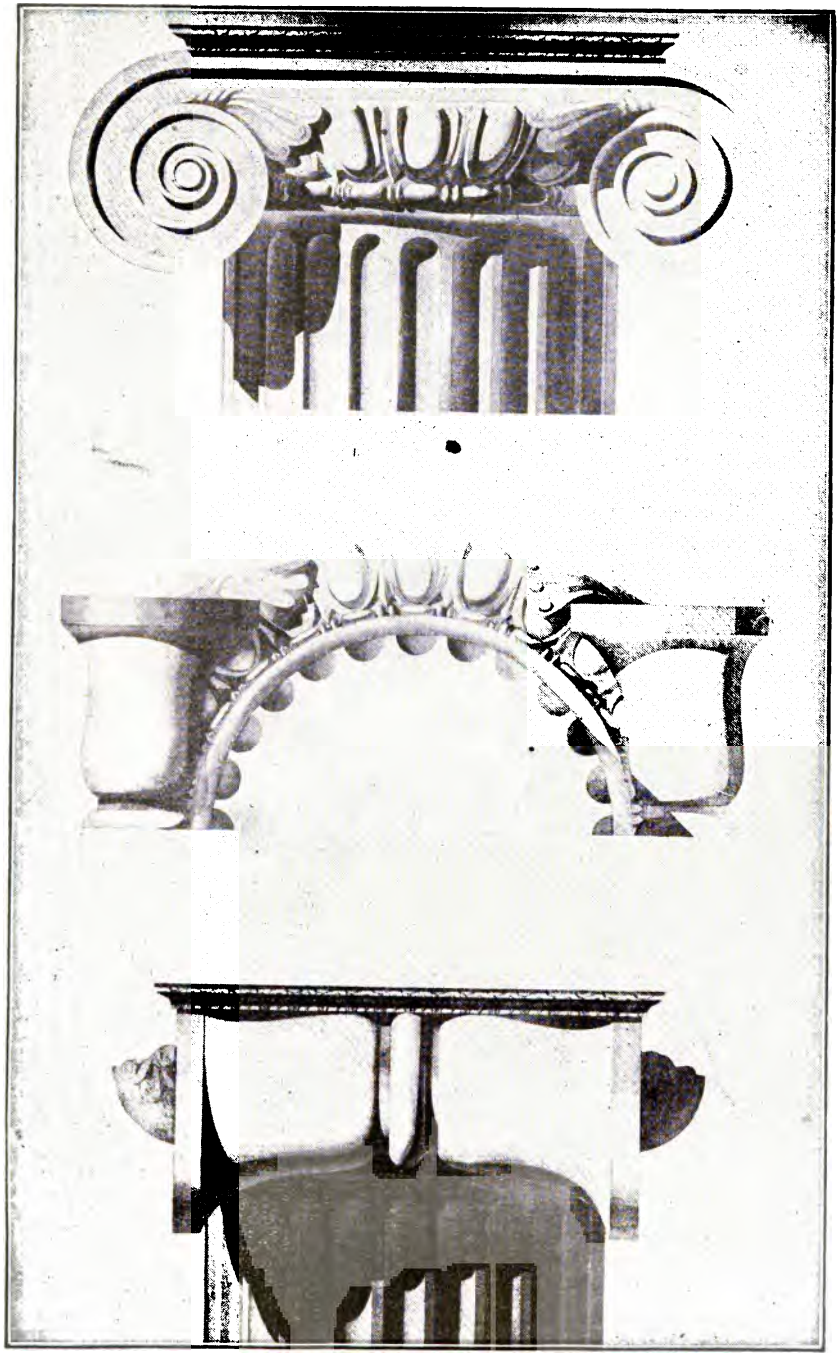


Fig. 6. Plan of Vestibule of Hotel des Monnaies.

Now consider the axes of the rows of columns 7 7. These are to be arranged in relation to the axes 3 3; finally the axes 8 8 are located in relation to the extreme axes 7 7, being checked in relation to the axes 2 2.

In the longitudinal direction the same process will be gone through, placing the first axis 1, then the extremes 2 2; by division 3 3 will be obtained, and dividing the spaces between the axes 1, 2, and 3, into half, the axes 5 and 6 of the columns are obtained. The secondary axes will be placed in the same way. Finally it will be found advisable to check up the different steps by verifying the distances of the secondary symmetrical axes from the central main axis.



RENDERING OF ROMAN IONIC CAPITAL
Showing conventional shadows and reflected lights and shadows
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In carefully studying the plan, and the different methods of drawing it, the student will become convinced that the methods of spacing the axes are of great importance, and that in this way he will arrive at exactness and will avoid many mistakes.

The student must understand that it is much more difficult to draw a good plan than is popularly supposed; more difficult, perhaps, than anything else, from the mere fact that everything builds up from the plan. In the plan especially, extreme exactness is necessary

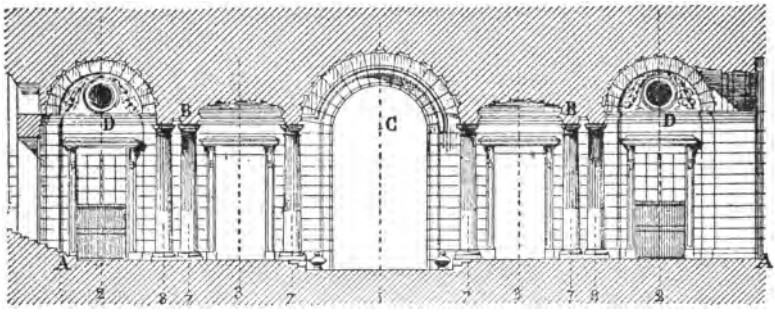


Fig. 7. Hotel des Monnaies, Transverse Section of Vestibule.
Section on YY.

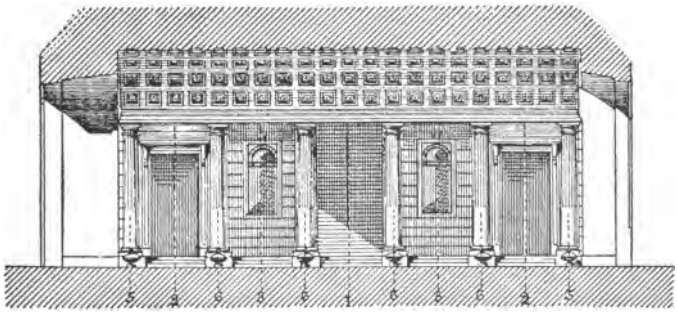


Fig. 8. Hotel des Monnaies, Longitudinal Section of Vestibule.
Section on ZZ.

and the student will do well, in order to become familiar with architectural drawing, to practice the drawing of plans constantly.

Now let us consider the sections, taking the same example that we have just considered. The student will easily see that the architect cannot study his composition thoroughly without the aid of numerous sections. Two sections, however, are especially necessary, those following the principal transverse and longitudinal axes of

symmetry. If the student wishes to draw both of them, he should decide first which one of the two controls the other. See Figs. 7 and 8. He will see that in this case it is the transverse section, parallel to the front elevation. The other, the longitudinal section, is chiefly the projection of elements of the other section. Therefore, in this case the drawing should be commenced by laying out the transverse section.

First, place the axes just as has been done in the plan, 1, 2 2, 3 3, 7 7, 8 8. In regard to the profiles or the parts in section, the first thing necessary is to locate the heights of the essential parts, taking for the first level the main floor A A, next drawing the upper line of the capitals of the columns B B, then the centers of the vaults C D.

Starting with these principal lines, draw in the details, as for example, the heights of the bases in relation to the floor A A. The capitals and heights of the architraves will be located in relation to the line B B. It is evident that if all the measurements were taken from the level of the main floor A A, the least inexactness would affect the capitals, while if the total height of the column A B is once determined, no mistake can be made in the height of the base and that of the capital, and even admitting a slight inexactness, it will be inappreciable on the total height of the shaft of the column.

In all which has preceded, the drawing has been laid out along the lines of the axes. But besides these are some conventional methods by which the drawing of profiles in section or in elevation can be facilitated. Let us take for example a fragment of the Doric order—one from the Parthenon, Fig. 9. To reproduce this drawing one should measure the different projections by referring them to one single vertical line. In this case the axis of the column would not furnish a convenient axis for measurement, as with exception of the column, it determines nothing. It is best to proceed just as in measuring an existing order, that is, by dropping a plumb line from the overhanging cornice and measuring the distance from that plumb line to the various members. But this vertical line from the outer member of the cornice will be only useful for laying out the profile and in locating the axis of the column; axes should be drawn in every other possible case. For instance, place the column on the axis A; the triglyphs, on B; the metopes, on C; the head of the lion, on D, etc. To obtain the heights draw the principal divisions in first; the total height of

the capital, the total height of the architrave, the complete frieze, the complete cornice; then draw in each detail in height within these first divisions.

The channels of the triglyphs, the guttae, etc., are all drawn in on their own axes. As for the channels of the column, these can only be drawn by projecting them. Do not copy them from the drawing, but draw out a plan, dividing the circumference into twenty parts or whatever number the design calls for, and project these divisions up to the elevation.

Study the model carefully before copying it; thus, in this example a close examination will show that the architrave is slightly sloping while the frieze is not. If the student has the opportunity to see mouldings similar to those which he is drawing, he should study them carefully. It cannot be too often repeated that architectural drawing should not confine itself to exercise for the hand; there should be the opportunity for real study of whatever is drawn.

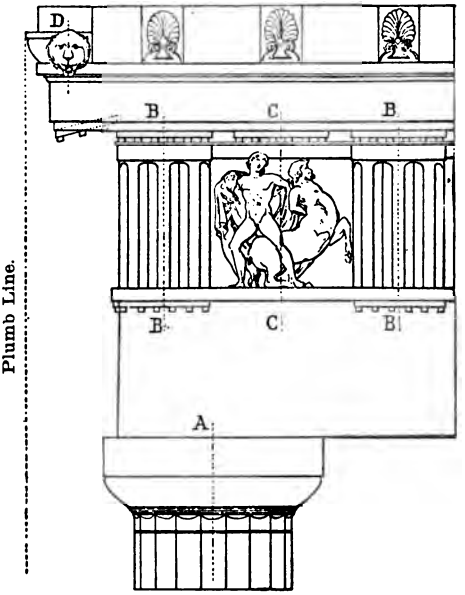


Fig. 9. Capital and Entablature from the Parthenon.

Limiting Lines. In geometry, we have learned what the *abscissa* and the *ordinate* are; *i.e.*, the elements of reference by which a point is referred to a system of fixed rectilinear co-ordinate axes. For every part of a design of which the elements are not geometrical lines, such as a right line or circle, the method of abscissa and ordinate is used, as in laying out profiles of mouldings or curved ornaments such as eggs in the egg and dart motive. Take for example a baluster, Fig. 10; it is evident that it should be drawn in relation to its axis. The student will mark the general divisions, A B the die, B C the base, C D the shaft, D E the capital, after which the secondary lines

of the mouldings should be drawn in. Between C and D, however, the profile of the shaft may vary very much and the student will not be able to copy it except by laying off horizontal divisions. For that purpose, draw the limiting lines of its greatest width *m m*, mark its point of application M, and repeat this operation on the drawing. In the same manner lay off the line *n n*, and the point N, which gives the smallest diameter of the shaft, and do not mark these points by a single point with the pencil, but be careful to draw the limiting (in this case vertical) lines at every point, and do not erase them until after you have inked in the drawing. These lines will be a safe guide and will enable one to make an exact and clean drawing.

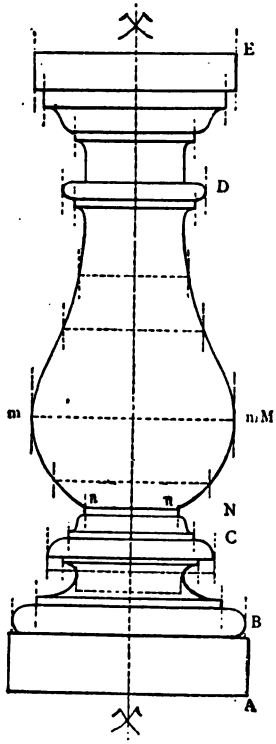


Fig. 10. Baluster.

As another example take the fragment of the cornice with different ornaments, taken from the Temple of Concord, at Rome, Fig. 11. The construction lines marked on the drawing, and which should be kept in pencil until the drawing is completed, show especially well the method previously explained.

Finally, to produce an architectural drawing with precision demands primarily a rational method and methodical habits. The design gains by its facility, but the method can only be a general one In its application, an intelligent draftsman will recognize each time what should be the logical sequence in carrying out the drawing. And still, all of this will be only the mechanism of the design; it is necessary to put into it taste and sentiment. For all of this there is only one precept—it is by practice that one becomes a good workman.

Oblique Projections. It happens often that in an elevation or section architectural motives are represented obliquely in relation to the principal plane of projection. Thus in a circular building a series of similar windows are in elevation at different angles, consequently the widths differ, but the heights do not.

It is necessary to become familiar with these conditions of drawing which occur frequently. It is here above all that geometry will be very useful, for that study includes the planes of projection and planes of development.

While there is some little difficulty, there is also much profit to be gained in projecting an architectural motive at an angle. In order to project a motive at an angle correctly, one must understand the motive thoroughly. An architectural arrangement drawn out in direct elevation only, will not tell the whole story, but if drawn in oblique projection a thorough understanding of the arrangement is gained.

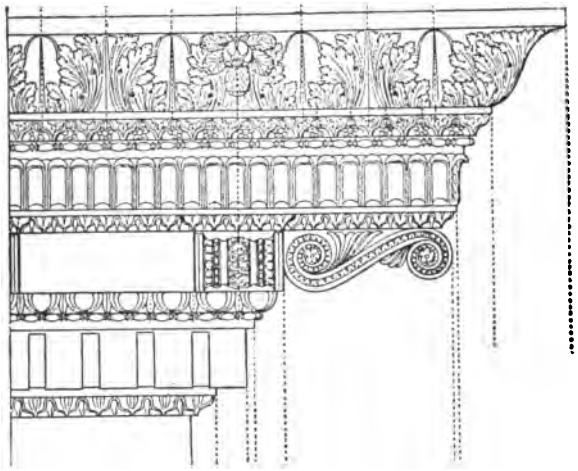


Fig 11. Entablature from the Temple of Concord, Rome.

It is recommended, therefore, as a very useful exercise to draw out in oblique projections, designs that are made in direct elevation; it is a good exercise in design, but above all it is an excellent preparation for architecture, compelling the designer to analyze his model and to see it *as a whole;* to understand its projections and to comprehend the position of the different details. The designer realizes that he is working on the real building rather than in simple imagination, and so will soon see of how much advantage these exercises will be to him.

Consider, for example, two windows, one in direct elevation and the other projected at an angle. It is evident that the direct eleva-

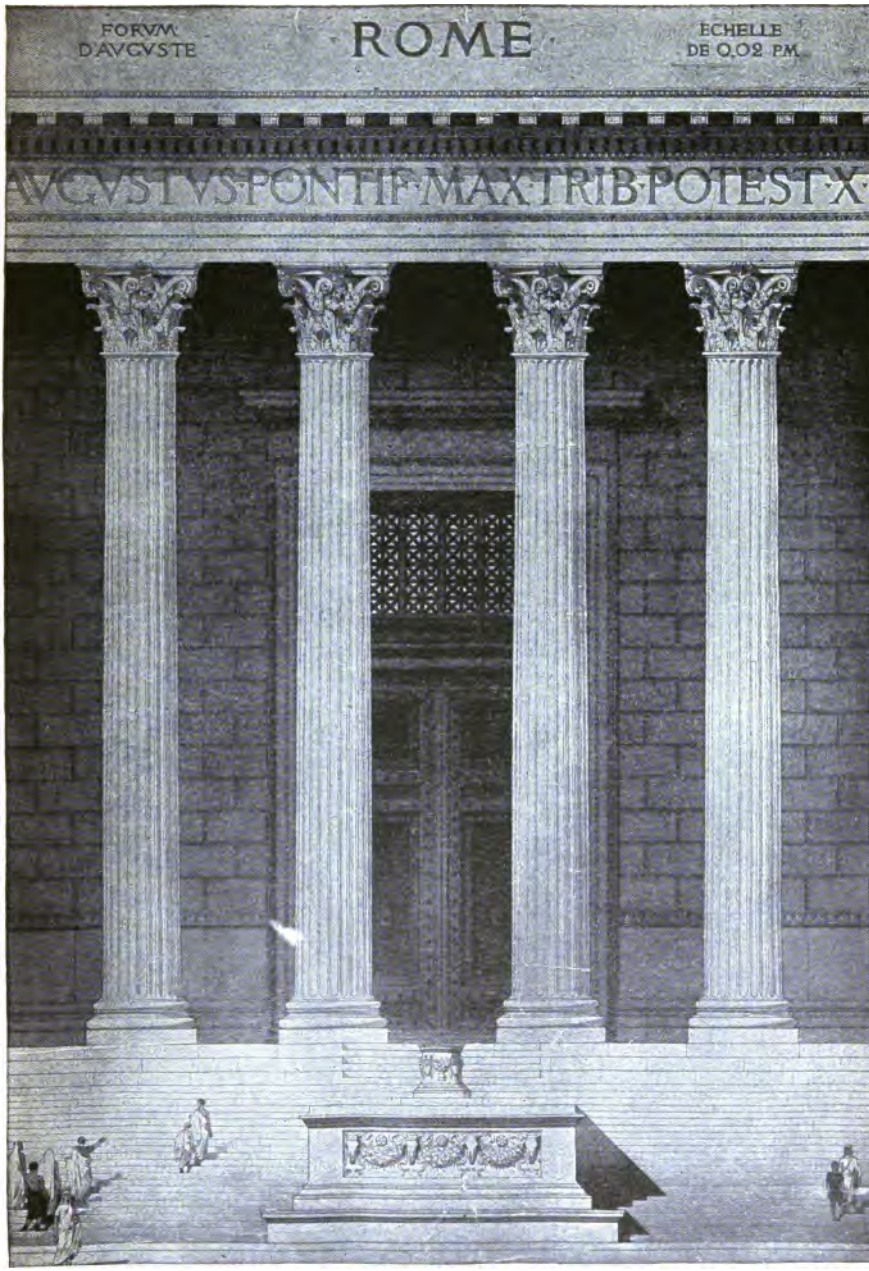
tion permits the study of proportions and it is evident also that the oblique projection shows more than the direct elevation of the different parts of the window. In the same manner draw out the development of such parts of buildings as vaultings, circular walls, etc.

All this can be summed up thus: Study architectural drawing as an architect. Become accustomed to see in the drawing the object represented. It is very necessary that the drawing should be nothing more for the designer than a sort of language, and that he should see in reality the thing itself, just as a composer of music, as he puts down on paper the notes of his score, can hear them as though they were being played; just as everyone in reading a book of printed characters never notices the printed letters but feels the emotions that are meant to be conveyed as though the words were spoken.

Modeling an Architectural Drawing. A design is only complete when in addition to the outlines, it is modeled, that is to say when the form is expressed. The most common process for modeling an architectural design is by wash drawing, but the methods of modeling are the same whether done by wash drawing or by rendering with the pen, the pencil, or other processes. It is not possible to say that modeling has absolute rules, or that all methods are good even if the desired effect is obtained; *i.e.*, if the reliefs and the forms are represented in their true relations to one another. There are, however, certain general principles that can be used as a guide in modeling a drawing.

Shadows at 45 Degrees. It is the custom to assume that the light rays fall in a direction, the horizontal and vertical projections of which make an angle of 45 degrees with the line of the ground. The luminous ray itself does not make, in reality, an angle of 45 degrees with the planes of projection. Its direction is that of the diagonal of a cube whose faces are respectively parallel and perpendicular to the planes of projection.

This method has two advantages; the laying out is easier, which it is well to consider, for the drawing of shadows is often a long and complicated process, and in this case the depth of the shadows is equal to the projections. Consequently, the size of the shadows permits anyone to understand, without further drawings, the projection of one architectural body in relation to another, and the relative positions in space of the different surfaces in one body.



DETAIL FROM TEMPLE OF MARS VENGEUR
An example of classic lettering, conventional shadows, and rendering
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The drawing of shadows is often difficult; it is one of the essential parts of descriptive geometry that will also be found in special treatises. As for indicating shadows which cannot be laid out accurately, such as shadows of decorative parts, it is a matter of judgment to determine the amount of projection—a knowledge gained by experience.

Values. After having drawn the shadows, lay over the shadow part a uniform tint. Now the drawing will be seen to be divided into lights and shadows.

As a first principle, it is necessary always to make a distinction between light and shade; shadows will always be modeled, lights will also always be modeled; but it is necessary to be able to distinguish clearly which is light and which is shade in the same drawing, at least where there are large spaces between different planes. The parts having the darkest tint in the light should remain lighter than the lightest reflected lights of the parts in shadow. Besides this, geometrical design, not being able to make use of the illusions of perspective to show distances and projections, has to make use of expressive modeling, since it is *the values* of the tints alone which will indicate the relative distances and projections.

Therefore, in order to bring forward or to set back one plane with relation to another, the only resource will be to tint them differently. Notice what happens in this respect in nature; for instance, an object placed near the eye is modeled very clearly and one at some distance is modeled much less, and one at a great distance or on the horizon, is only a mass without details. So, the nearer the object is, the more it is modeled and the greater are the differences between the shadows and the lights; on the contrary, the further away it is the more the lights and shadows tend to mingle. In the foreground there will be strong shadows and high lights, in the distance dull shadows and softened lights; between these an intermediate proportion of shadows and lights. Therefore, in facade, the planes farthest away from the eye will have the least modeling, while the nearer the plane is to the eye, the more is the modeling accented.

As stated above, in nature every light and every shade is modeled and graded; the shadows are more noticeably graded than the lights. The reason for this gradation of shadows is the indirect lighting

thrown back on the shaded objects by neighboring lighted objects, and this is called reflected light.

Take for example a cylindrical body like the shaft of a column. It is easy to distinguish on this cylinder cast shadows and shades. The cast shadows are those which result from the interception by another solid, of luminous rays which without it would have lighted the cylinder. Shades result from the absence of light on the part of the cylinder which by its position cannot receive light rays. Naturally shadows are less affected by reflected light than shades. The reflection of light or the throwing back of light which creates the reflected light comes from lighted bodies, which in theory may be considered as secondary sources of rays of light of which the resultant will be in the direction opposite to the light. That is, since the lighting is in a direction of 45 degrees from above down, and conventionally from left to right, the direction of the reflected light is in the direction of a diagonal from the lower right front corner to the upper rear left corner.

This conventional theory is to be followed as the rule for modeling. Commence with the lights, or where the gradations are more easily comprehended. Take a solid of white stone, for example, a sphere. It is easy to comprehend that the strongest lighting will be at the point of intersection of the surface of the sphere with the luminous ray which prolonged will pass through the center. Then, around this pole of light, the angle of the luminous ray with the surface will be diminishing constantly following parallel zones, having the luminous point for the pole, until it becomes tangent to the sphere following a great circle whose luminous point is also the pole and which will be the line separating the shade from the light. In other words, the light will diminish from the pole to this equator.

In the shadow it will be just the opposite; the greatest reflection will be at the other extreme of the ray prolonged to pass through the luminous point and the center of the sphere, the shadow will increase in intensity from the pole of reflected light to the separating circle of shade and light.

But if any body casts a shadow on the lighted part of the sphere, its shadow will be much less affected by reflected light and consequently will be more intense than the shade itself.

From this follow two rules for modeling: (1) A shadow cannot

be cast on a body unless this body is in the light and some other body is casting the shadow; (2) The value of the intensity, *i.e.*, the degree of darkness, of the cast shadow at any point is in direct ratio to the strength of light on that point.

The application of these rules can be illustrated on a geometric body, for example, the capital of a Doric column and its architrave,

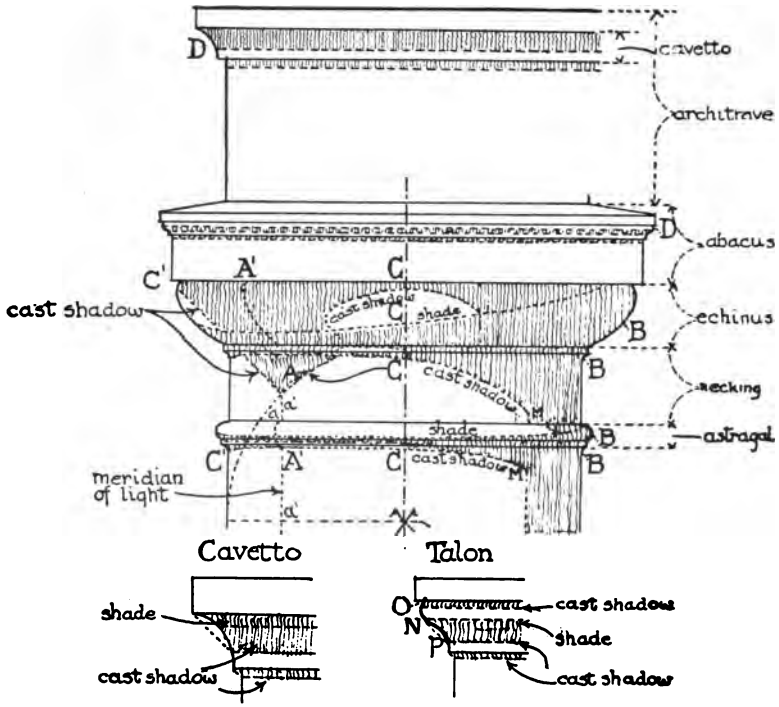

Fig. 12. Shadows on Capital of Doric Column.

Fig. 12. The shadows should be drawn out and a light shadow tint laid over them. Now let us consider where the most intense shadows will be. Evidently at A, where the shadow is determined by a ray normal to the cylindrical surface of a column, and the parts A′ A′, of the cast shadows which meet the surface of revolution following its meridian of light. The clearest reflected shadows cannot be seen in the drawing as they will be found at the back of the projection on the meridian opposite the point A. But among the parts seen on the drawing the most reflected light will be at the point B B, doubly lighted by its position on plan and by the form of the moulding.

Between these extremes the parts C C will have intermediate values, whether shades themselves or cast shadows. Also, observe that the values of the light at contour C′ are symmetrical with the values of the light of contour C. There will be, therefore, a symmetry of modeling, in relation to an axis of the most intense lighting on the column of the luminous part and of the intensity of the shadows; this axis will be on meridian A. As for the mouldings which are straight in plan like D D, their general value will be analogous to the intermediate value C C.

Passing to the lights, we see that the point most lighted will be the point *a*, and finally the generatrix *a′ a′;* and the light will become more and more gray up to the tangent M M. But along the astragal the light will extend in almost uniform intensity, for it will strike more normally than on the cylinder. As for the straight parts, the abacus, the architrave and fillets, they will receive less light than the cylinder at *a′ a′* and approximately the same as at C C; the sloping part of the abacus will naturally have a more intense light. Otherwise each one of the plain surfaces, in shadow or light, will be graded from the upper part down, because the nearer the surface is to the ground, the more reflected light it receives. For each detail use the same reasoning. Thus, for the cavetto, there is a cast shadow in the lower part, but the portion above the tangent is in shade. The shadow is modelled by continuous grading from darkest at the lower part to the lightest in the upper part; the talon will have cast shadows at O and P, the portions at N being in shade, hence O and P are the darkest parts while N is the lightest.

Another element comes into the modeling; *i.e.*, the openings. An opening is always darker than the simple shadows, for there is almost no reflection that comes in the opening to lighten the shadow. Such are the door and window openings of a facade. The parts in shadow, which are less accessible to the reflections, will be darker than the other parts. For instance, the openings between the dentils, the spaces between the consoles, etc., will be darker than the face of the dentils or consoles and may be as dark as the general shade of the openings. The modeling should be such that the parts which are by themselves in reality, will appear so on the drawing. It is not necessary to exaggerate; the modeling should remain simple.

Lacking good models, it is always easy to get good photographs

CORINTHIAN CAPITAL AND BASE
Showing conventional shadows and rendering
Original drawing by Emanuel Brune
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of good wash drawings; for example, a large number of "Envois de Rome", or drawings made by students in Rome, have been photographed and published. These are models which cannot mislead one.

RENDERING IN WASH.

All studies and completed exhibition drawings in the architectural schools are tinted in India ink or water-color. This is done to show the shadows, and to indicate the relative position of the different planes, and is the method of representation in common use in architects' offices, especially in the presentation of competition drawings.

MATERIALS.

Chinese, Japanese or India inks are used for rendering, on account of their clear quality and rich neutral tone. The ink comes in sticks, Fig. 13, and it is ground in a slate slab provided with a piece of glass for a cover. See Fig. 14.

Fig. 13. India Ink.

There are various kinds of brushes. Camel's hair brushes are the cheapest and are useful for rough work. Sable brushes, Fig. 15, are two to three times as expensive as the camel's hair ones on

Fig. 14. Ink Slab.

account of the material, but are also very much better. The sable brushes have a spring to them not to be found in the camel's hair brush, and they come to a finer, firmer point. Chinese and

Japanese brushes are used a good deal of late, as they are cheaper than the sable brushes and have some spring to them. A stippling brush is one with a square end, used mostly in china painting. A bristle brush is a stiff brush used in oil painting; on account of its stiffness it is used for taking out hard edges, as described later on. Fig. 16 shows a nest of porcelain cabinet saucers.

Fig. 15. Sable Brush.

Besides these materials the student should provide himself with a large and a small soft sponge, and large blotters, which will sop up water readily. Whatman's "cold pressed" paper is the best paper to use for rendering in India ink.

METHOD OF PROCEDURE.

Stretching Paper. All drawings on which washes are to be laid should be stretched, as described in the Mechanical Drawing, Part 1.

Fig. 16. Nest of Saucers.

Inking the Drawing. The lines should be drawn with ground India ink, the ink being as black as possible without being too thick to flow. Ornament should be inked in with lighter lines than the vertical and horizontal lines. This accents the structural lines. Very often the outline of the ornament is drawn in a heavier line than the remainder. The width of the line

should vary with the scale of the drawing, the larger and bolder the drawing the wider the line.

India ink evaporates very rapidly. It should be kept covered and changed several times a day, especially in summer. After the drawing is inked it should be washed to remove the surplus ink, otherwise when the tint is applied the ink will spread. This is best done by placing it under a faucet and rubbing it *very* lightly with a soft sponge. If the inking has been properly done the lines will now have the appearance of a firm pencil line of a soft neutral color forming a harmonious background for the tint. The shadows should then be cast and drawn in with a hard pencil in *faint* lines.

Preparing the Tint. For large washes India ink should be freshly ground in a clean saucer each time it is required. In no case use the prepared India ink which comes in bottles, as this is full of sediment which settles out in streaks on the drawing. Always use the stick ink.

Rub the ink in the saucer until it is *very* black; then let it stand, keeping the saucer covered. This allows the sediment, which is so fatal to a clear wash, to settle. After it has settled take the ink from the top with a brush without disturbing the bottom. Put this ink into another saucer and dilute it with the necessary amount of water. Never use the ink in the saucer in which it was originally ground. In dipping the brush into the second saucer it is well to take this ink also from the surface and thus avoid stirring any sediment which may still remain in the ink. In other words, the sediment which is found in even the most carefully ground ink should never be used for washes, otherwise streaks and spots may show in the washes.

Where only a small surface is to be rendered the tint can be mixed on a piece of paper in the same manner in which it is mixed in the saucer. Thus various shades can be obtained more quickly and experiments made more easily. Skill in laying washes is only acquired by practice. However, some instruction is necessary. If, after all possible care has been taken during the drawing, such as placing paper under the hand to keep the paper from getting greasy and keeping the drawing covered to protect it from the dust, the paper has nevertheless become soiled, it should be

cleaned by giving it a light sponging with a very soft sponge and perfectly clean water. Touch the surface lightly, sop on the water liberally, and dry it off immediately with a sponge or blotter *without rubbing.* Before washing, the paper should be cleaned by rubbing it *very* lightly with a soft rubber. Especial care must be taken not to injure the surface of the paper by rubbing too hard.

It may seem that all this care is unnecessary, but it is only by observing this extreme care that the skilled draftsman obtains the transparent wash and the beautiful, even, clear tints free from all streaks, which give so much charm to an India ink rendering.

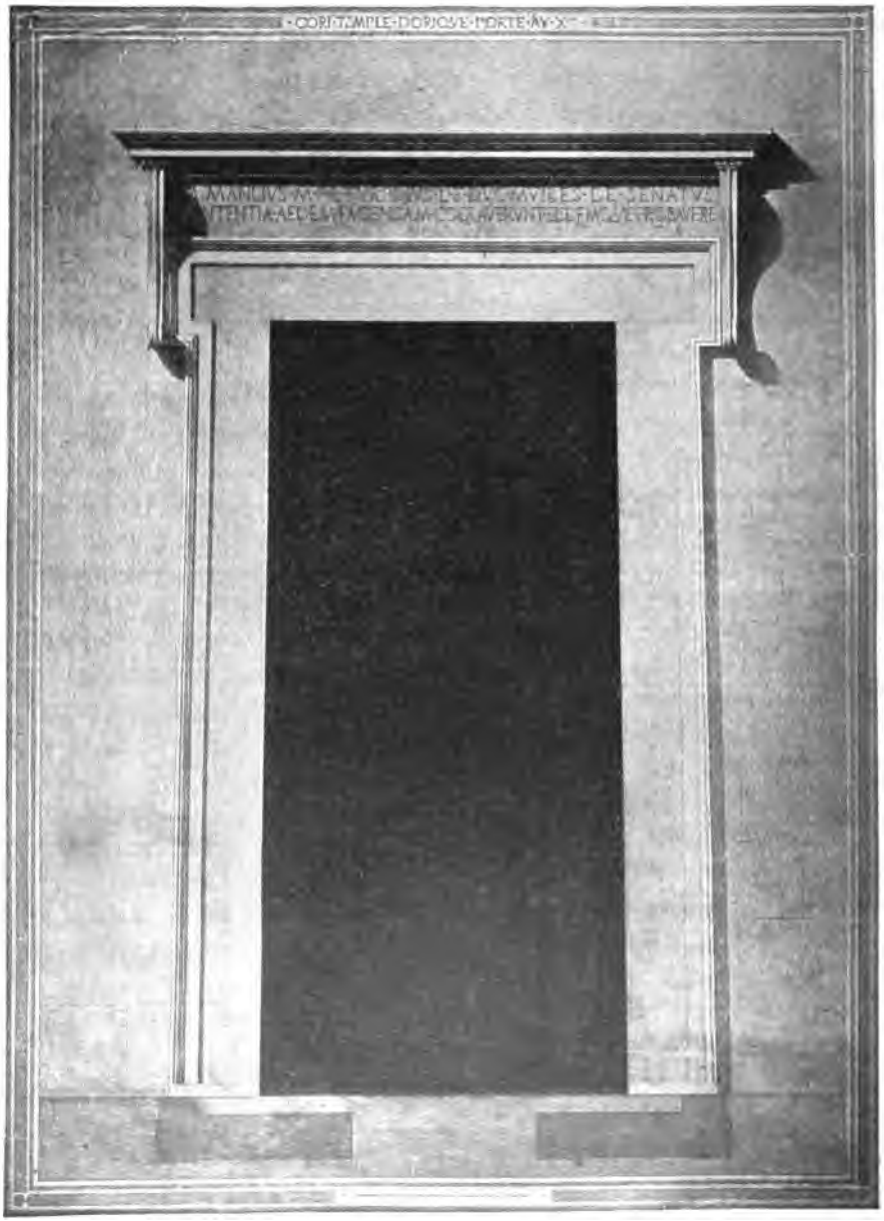
Handling the Brush. Skill in handling the brush is acquired only by constant practice. The brush demands great lightness of hand. The right arm should never support the body. The arm should not rest on the drawing; only the little finger of the right hand should come in contact with the paper. The brush should be held somewhat like a pencil between the thumb and index finger, and the little finger should be very free in its movements. Touch the paper only with the point of the brush.

The brush should be well filled with the tint and care should be taken that there is practically the same amount of tint in the brush at all times. If this is not done, for example, if the brush is allowed to get too dry, one part of the wash will dry faster than the other and streaks will result.

If the brush should be too wet, the surplus moisture can be removed by touching it to blotting paper.

If the paper is too wet the surplus tint can be removed by drying the brush on blotting paper and applying it to the surplus tint which will then be rapidly absorbed by the brush. Great care must be taken not to remove too much of the tint; otherwise it will dry too fast and leave a streak.

Laying Washes. There are two kinds of washes; the clear washes used in rendering shadows, window openings, etc., and the washes in which the color is allowed to settle, the latter being used to render the grounds surrounding a building. When laying clear washes it is better to tip the board slightly so that the washes may flow slowly in the direction in which they are being carried. If the board is placed flat there is danger of the wash running back over the part that is already dry and thus forming a streak.



DORIC DOORWAY FROM ROMAN TEMPLE AT CORI, ITALY
An example of classic lettering, conventional shadows, and rendering
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The edge of the wash should always be kept wet, for if it begins to dry a streak will surely follow. The tint should be carried down evenly across the board, moving the brush rapidly from side to side so that one side does not advance faster than the other. Carry the tint down about an inch at a time, the amount depending upon the size of the brush and of the surface rendered. Always go over the previous half inch at every new advance, taking care not to touch any part that has already dried. In this way the tint will dry gradually, parallel to the work. Carry the sides of the tint forward a little more slowly than the center. This will make the tint run towards the center and help to avoid the lines or streaks due to uneven drying.

The tint should be carried forward in such a way that the paper will be thoroughly and evenly wet. In fact, it is a very good plan to dampen the entire drawing with a soft sponge before beginning to lay a wash. This dampening should be carried well beyond the edges of the drawing so as to prevent the color from spreading to the drier and more absorbent parts of the paper. Always remove the pool of tint which remains at the bottom of a wash in the manner described under "Handling the Brush." If allowed to remain it will dry more slowly than the rest of the drawing and a streak will show.

The drawing board should be left inclined until the wash is dry. Never lay one wash over another before the previous one is absolutely dry.

In laying washes which grade gradually, either from dark to light or light to dark, grade the tint by the addition of water or color each time that an advance is made, and be careful that these additions are such that the change in color is made evenly.

It is very difficult to lay an evenly graded dark tint with one wash only. It is usually better to lay a light flat wash or a light graded wash to serve for a background on which to lay the dark graded wash. By a flat wash is meant a wash which is the same tone or color throughout; that is, a wash that is not graded. See opening in Doric Doorway, Roman Temple, Cori, opposite page.

Water has to be added constantly in grading. Where there is a series of graded washes, as in successive window openings, it is better to have two or three saucers containing tints of different

strength and carry each tint for the same distance in each window so that the gradation of color may be the same. In grading in this way it is necessary to carry each new wash well back over the old one so the point where one tint ends and another begins may not show.

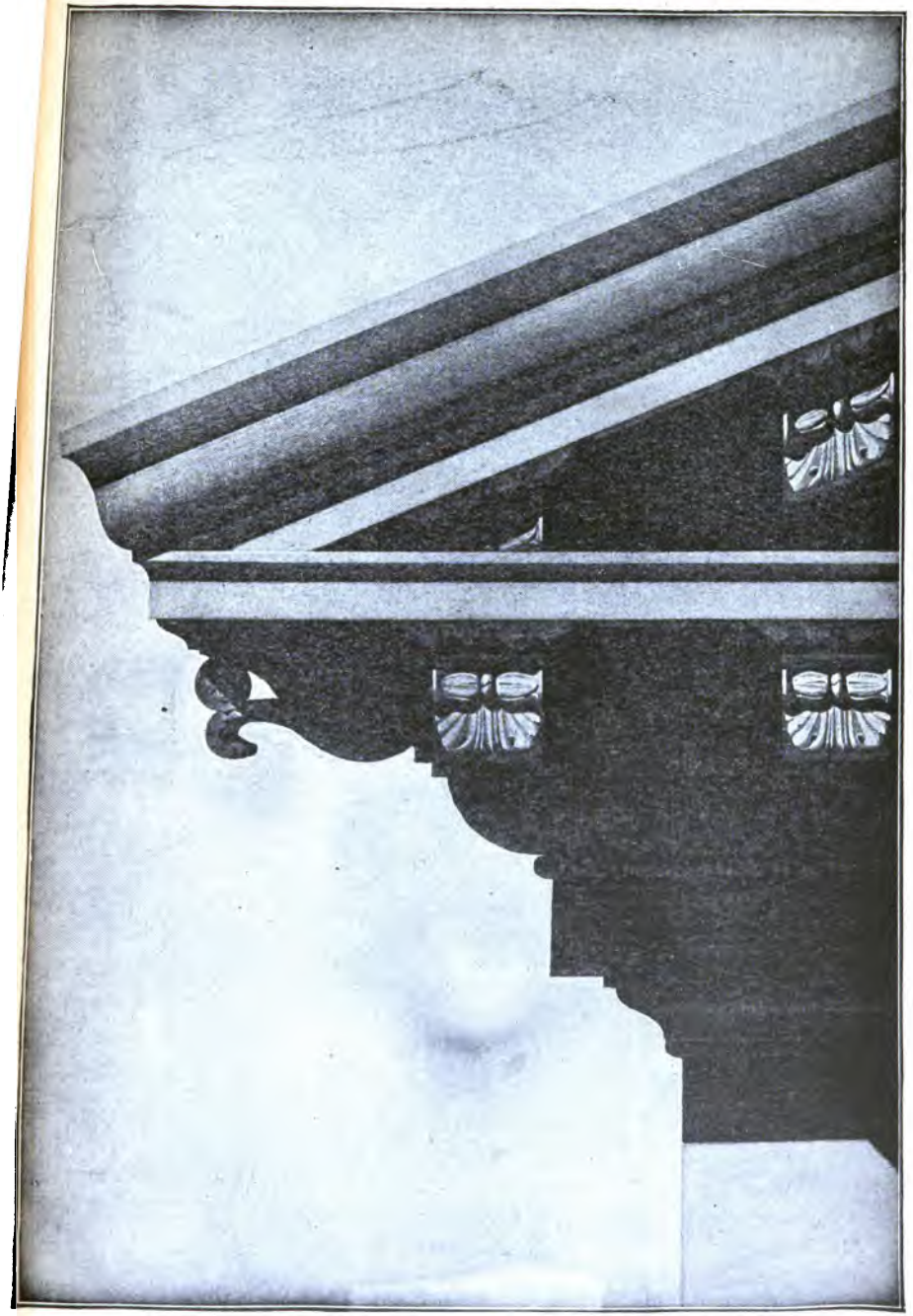
Sometimes gradations are obtained by laying successive flat washes, each wash beginning a little lower than the previous one. In this way the rendered surface will begin with one flat tint and end with a number of tints, one on top of the other. This is called the French method and is done by drawing *very* faint parallel lines at close intervals to mark the limit of each wash. A very light wash is then put over the whole surface, and this is followed with successive washes, each starting from the next lower line. This method is especially good for rendering narrow, long, horizontal graded washes. See rendering of mouldings in classical cornice opposite. Note particularly the application of this method on the crown moulding, and practically all the curved mouldings.

Avoid laying too many washes in the same place, as the continuous wetting and rubbing which the paper gets from the brush is liable to injure the surface.

If the tints are too dark, a soft sponge can be used to lighten them or to take out hard or dark border lines; but a large brush about two inches wide is still better for this purpose. If it is necessary to use a sponge, use it with a great deal of water, rub *very* lightly and very patiently. The water should be kept *very* clean, and the surrounding parts should be thoroughly wet before wetting the tinted part, otherwise the tint may spread over the other parts of the drawing. After using the sponge, dry the paper carefully with a clean blotter. Another and better way is to place the whole drawing under the faucet, turn on the water and use the sponge or brush, as already described, on the parts to be lightened.

To make light places darker, use the point of a brush, applying the tint in small dots. Be careful not to begin with too dark a tint. This process is called stippling, and it must be done very gradually and very carefully.

Do not forget that the first quality of a wash is crispness. It is necessary to draw with the same precision with a brush as with a pencil. When the drawing is finished it should be allowed to dry thoroughly before it is cut from the drawing board.



CLASSICAL CORNICE SHOWING LIGHTS AND SHADOWS AND FRENCH METHOD OF RENDERING

Rendering Elevations. The object of rendering a drawing is to explain the building. Those parts of the building nearest to the spectator should show the greatest contrast in light and dark, for in nature, as an object recedes from the eye, the contrast becomes feebler and feebler and finally vanishes in a monotone. Every elevation shows the horizontal and vertical dimensions of a building, or details of a building, but in a line drawing the projections of the different parts when in direct front elevation are not shown; and it is to indicate these projections that the shadows are cast and the drawing is rendered. The appearance of a building or any details of a building will be clearly shown by the shadows in their different values of light and dark. See opposite pages 18 and 23. The windows and other openings of a building should be colored dark, but not black—although this is sometimes required in competition drawings—and varying lighter tints should be used to indicate the color of the material in the roof and walls, the difference in the color intensity indicating the varying distances from the spectator. Note, opposite page 5, the comparative values of rendering in roof and shadows on roof; also portions of order in light, portions in shadow, and background of column. This method of drawing is frequently carried to an elaborate extent by showing high lights, reflected shadows, etc., and an elevation can thus be made to show almost as much of the character of the proposed building as would be shown by a perspective view or by a photograph of the completed structure. See opposite page 1, "Fragments from Roman Temple at Cori." Study the different tone values of the various objects in the foreground and in the background, and note the perspective effect of the background.

It is a good plan, before starting to render a drawing, to make a small pencil sketch to determine the tone values which the various surfaces should have, so that they will assume their proper relative positions in the picture.

Drawings of this kind are much superior to any others as a means of studying the probable effect of the building to be constructed, as they show the character of the building and, at the same time, dimensions can be figured directly on the drawing. It is difficult and unusual to give measurements on a perspective drawing

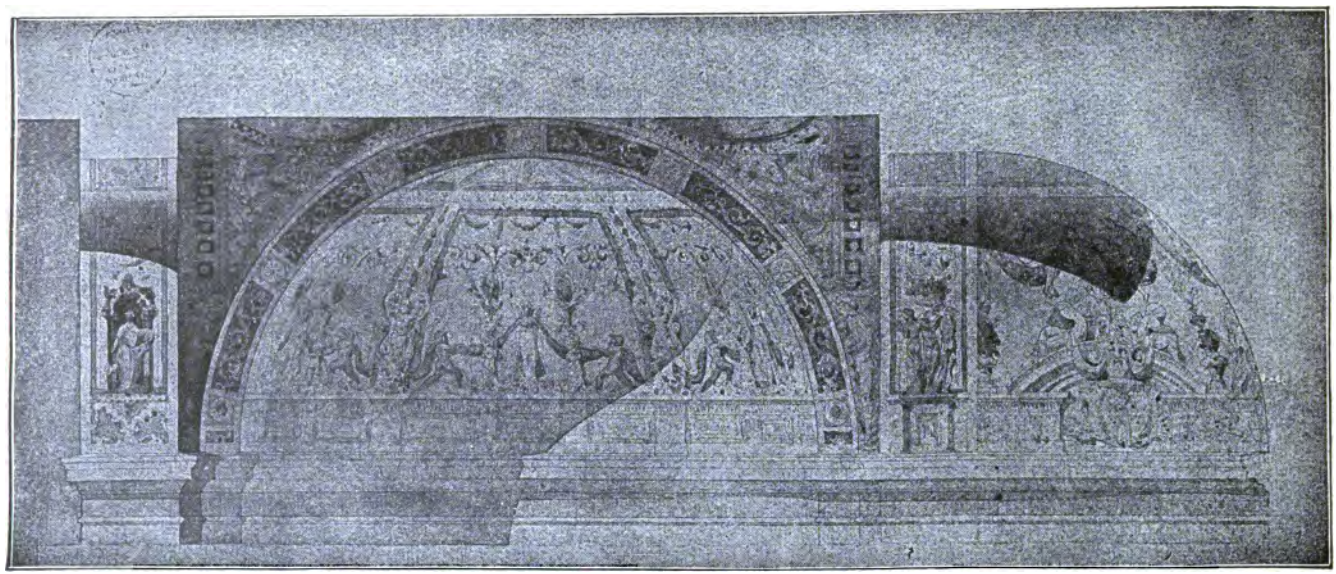
Rendering Sections and Plans. Sections are frequently rendered in the same manner as elevations to show the interior of buildings. The shadows are cast in such a way that they show the dimensions and shapes of the rooms. The parts actually in section are outlined with a somewhat heavier line and tinted with a light tint. The surfaces are modeled just as they are in the elevations. See opposite page.

Plans are rendered to show the character of the different rooms by tinting the mosaic, furniture, surrounding grounds, trees, walks, etc. The shadows of walls, statuary, columns, and furniture are often cast, so that the completed rendered plan is an architectural composition which tells more than any other drawing the character of the finished building.

The interior of the building and all covered porticoes are left much lighter than the surrounding grounds because the building is the most important portion of a drawing and should, therefore, receive the first attention of the spectator. The sharp contrast of the black and white of the plan to the surroundings brings about the desired effect. The mosaic, furniture, etc., should be put in in very light tints in order to avoid giving the plan a spotty look. The walls in the plan should be tinted dark or blacked in so that they will stand out clearly. See Fig. 17.

Graded Tints. One rule in laying all tints should be strictly followed: *Grade every wash.* A careful study of the actual shadows on buildings will show that each shadow varies slightly in degree of darkness; that is, shows a gradation. The lower parts of window openings are, as a rule, lighter than the upper parts. Therefore, the washes or tints should grade from dark at the top of the door or window openings to light at the bottom. Furthermore, it will be found that the reflection from the ground lights up shadows cast on the building, so that shadows which are dark at the top become almost as light as the rest of the building at its base.

Windows and doors are voids in the facade of a building, and they have a greater value in the composition of a design than shadows or ornaments in general. This character should be carefully shown in the rendering; and to that end the grading should never show such violent contrasts as to distract the eye from the design as a whole, and thus destroy the unity of the design and



SECTION THROUGH VAULTED CEILING, SHOWING CONVENTIONAL SHADOWS AND METHOD OF RENDERING

the true mass of the openings. Many good designs are greatly injured in the rendering by the violent contrast in the grading of the openings from dark to light.

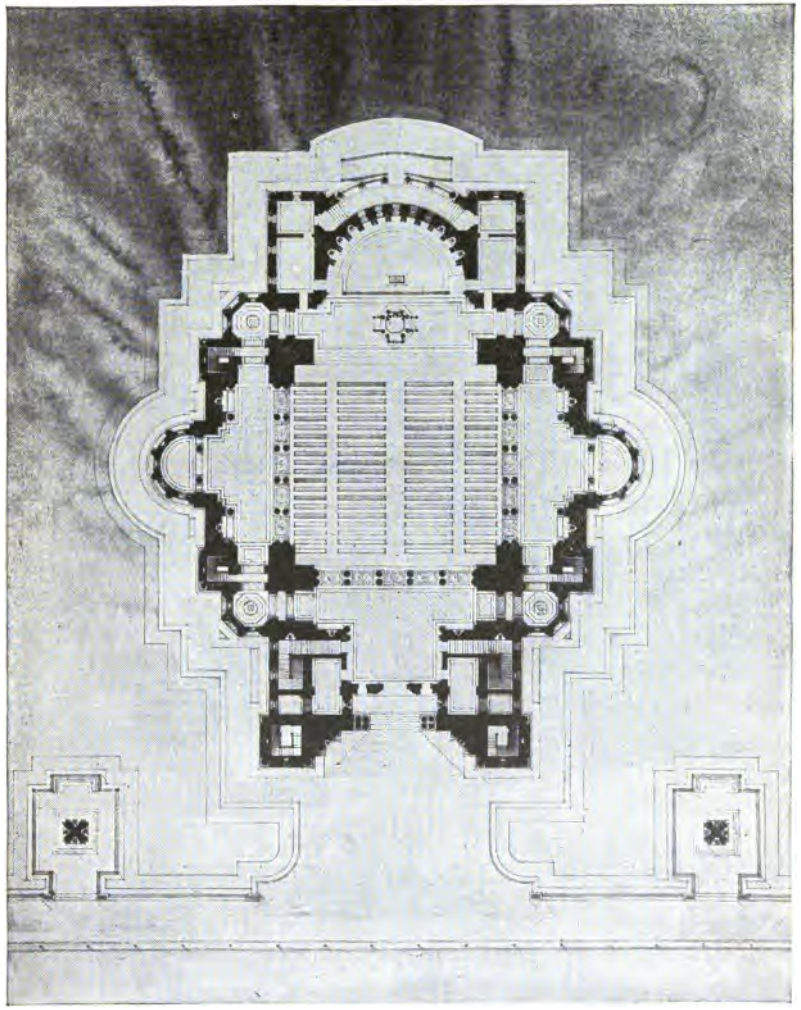


Fig. 17. Conventional Method of Rendering Plan

In the shadow itself it will be found that detail is accented or brought out by reflected shadows. These shadows are in a direction opposite to the shadows cast by the sun. If the light is

assumed to come in the conventional way, namely at an angle of forty-five degrees from the upper front left corner to the lower back right corner, the reflected light may be assumed to be at an angle of forty-five degrees from the lower right front corner to the upper left rear corner, and the reflected shadows will accordingly be cast in this direction. Note the fine example of conventional shadows and rendering in the illustration opposite page 5.

If these shadows are carefully worked up in the wash drawing in their correct relation to one another the character of the details will be well expressed.

Distinction Between Different Planes. The different planes of a building which project one in front of the other are distinguished from each other in the following manner:

The parts toward the front have a warm color, the portions receiving direct light have a tone over them indicating the material, the shadows are strong and bold, and the reflected shadows are more or less pronounced. The parts toward the rear, on the other hand, have no such strong contrasts of light and dark. The light parts are often left very light and the shadows put in even tones. The further the object is from the spectator the less pronounced will be the reflected lights and shadows. Note the grading on the steps in plate opposite page 18, and study the frontispiece opposite page one as an illustration of this point.

In rendering, a difference should be made for different materials. Note the difference between the stone and the metal work on opposite page.

A FEW WATER COLOR HINTS FOR DRAFTSMEN.

Many draftsmen who are strong in drawing, are very weak in color work. The reason for this is, in most cases, that the colors are not fresh, that the brush is too dry, and that the color values are not correct. *Fresh* crisp color is most important. To get this it is necessary to start with a clean color box, clean brushes, and clean paints. The colors should be moist and not dry and hard.

Tube and Pan Colors. After having acquired some facility in the use of colors, tube colors are the best to use, although they are somewhat more wasteful than pan colors. They are less likely to harden and dry up and are not more expensive. The

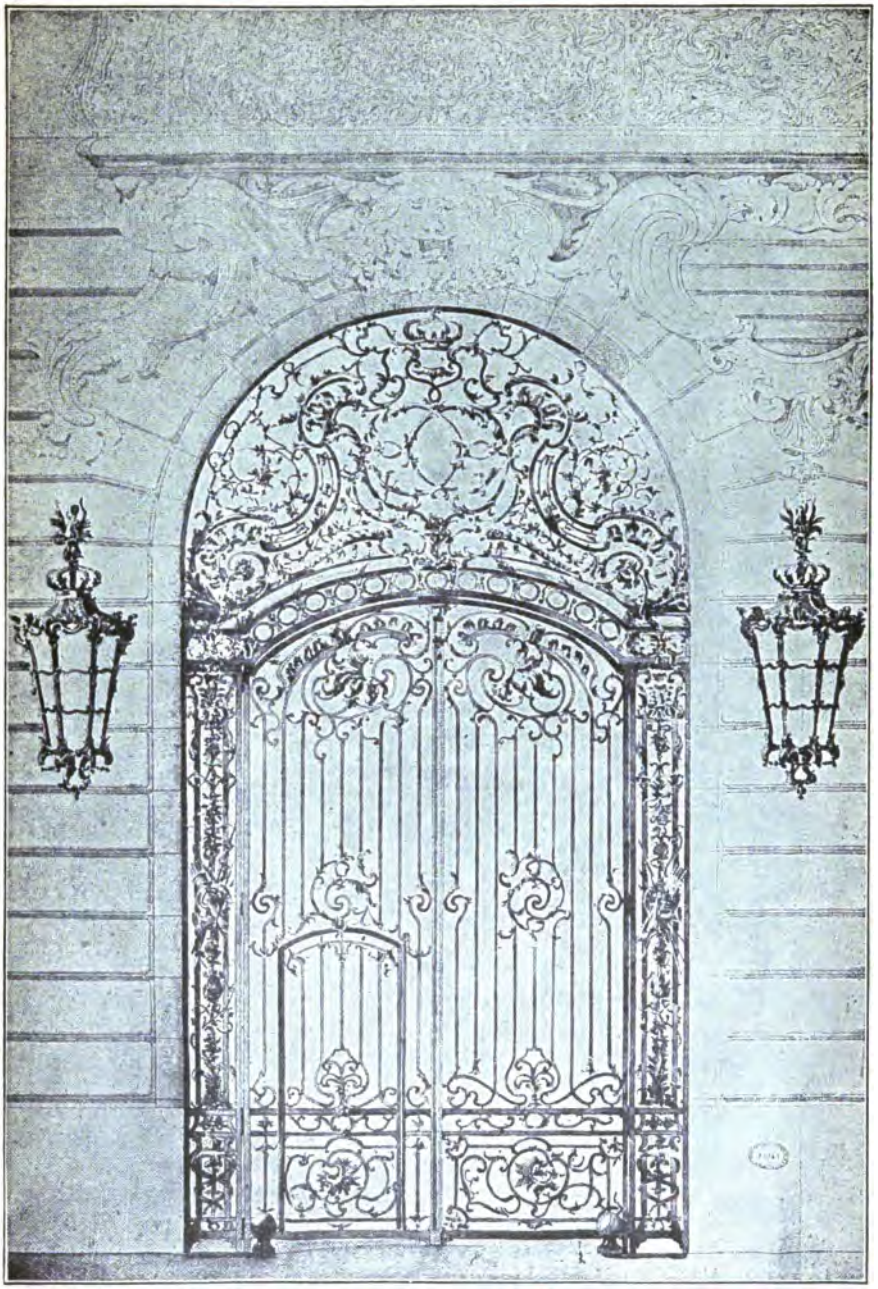


ILLUSTRATION OF THE DIFFERENCE IN RENDERING STONE AND METAL

colors in the tubes can be squeezed out on the palette as needed, and if this is done fresh bright effects are obtained. For the be-

Fig. 18. Box for Pan Colors.

ginner, however, pan colors are recommeded, as they are more easy to handle. Fig. 18 shows a japanned tin box for pan colors, Fig. 19 shows a pan color, and Fig. 20 a tube color.

List of Colors: The following list of colors will make a very good palette:

Cadmium	Orange Vermilion	Cobalt Blue	Emerald Green
Indian Yellow	*Carmine*	New Blue	*Hooker's Green*
Lemon Yellow	Light Red	*Prussian Blue*	
Gallstone	Burnt Sienna	*Paine's Gray*	Chinese White
Yellow Ochre	*Warm Sepia*		

The colors printed in italics are clear colors which will give clear even washes. The others will settle out, the color settling

Fig. 19. Pan Color.

Fig. 20. Tube Color.

into the pores of the paper producing many small spots. This effect is often desirable, giving a texture which cannot be obtained with the clear colors.

For use in the offices, India ink, Chinese white, gallstone, carmine and indigo will be found very convenient. The latter three are convenient forms of the three primary colors to use with India ink in rendering. Many draftsmen use these alone.

Manipulation. The washed-out look of many of the color sketches seen in architectural exhibitions is very noticeable. The sketches lack strength and crispness.

Color properly applied should be put on boldly in broad simple washes without fear of too much color. Remember that colors when dry are much lighter than when in a moist state. Use plenty of clear water in the brush. Do not go over one wash with another before the first is entirely dry. This is particularly true where a deeper tone is to be put over a lighter one. In broad sky washes where there is a great deal of paper to be covered, dampen the surface well first with a small sponge, then with a large brush and bold yet light quick strokes put in the sky.

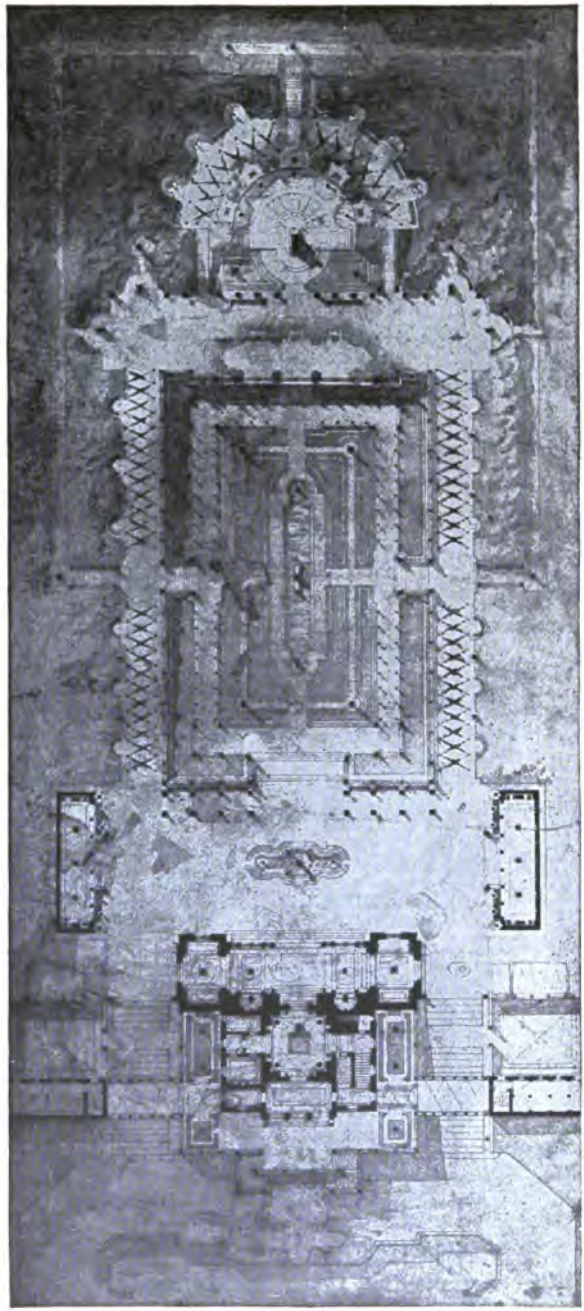
Brushes and Paper. A small brush with a good point is necessary for "drawing in" and for detail. A bristle brush is very useful to remove color and to soften hard lines. Chinese brushes are very good, as they hold a great deal of color and at the same time have a good point.

If an edge shows a hard line, this can be softened by dipping the bristle brush into clean water and rubbing the point lightly over the edge that is too hard, sopping up the water at frequent intervals with a clean blotter. It is important that plenty of *clean* water should be used and that the water be taken up with a blotter very often.

When a "high light" is lost, and a bristle brush does not take out enough color, the "high light" may be put in with Chinese white, mixing it with a little of the color of the material.

Look at your subject broadly and do not try to put in too many details. Whatman's hot pressed 70- or 90-lb. paper is good to use. The hot pressed paper, which has a smooth surface, takes the color better than the rough surfaced or cold pressed paper, but the cold pressed has more texture and gives better atmospheric effects.

Combination of Color. For the inexperienced a few hints as to what combinations of color to use may be helpful. It must



CONVENTIONAL METHOD OF REPRESENTING PLAN AND SURROUNDING GROUNDS BY WASH DRAWING

always be remembered that the colors must be clean to get fresh bright effects.

A simple blue sky: Prussian Blue, Antwerp Blue or Cobalt Blue.

Clouds: Light Red. For the distance use lighter tones with the addition of a little Emerald Green or Carmine.

Dark part of clouds: Light Red and New Blue.

Roads and pathways in sunlight: Yellow Ochre and Light Red with a little New Blue to gray it.

Cast shadows: Cobalt and Light Red or Carmine with a little green added.

Grass in sunlight: Lemon Yellow and Emerald or Hooker's Green; or Indian Yellow and Emerald Green.

Grass in shadow: Prussian Blue and Indian Red; or Prussian Blue and Burnt Sienna. Aurora Yellow and Prussian Blue gives a green color similar to Emerald.

For gray roofs in sunlight: Light Red and New Blue.

Primary, Secondary and Complementary Colors. The combination of colors may be learned by means of the diagram, Fig. 21, which will assist the student greatly in his water color work. The three primary colors are yellow, red and blue. The combination of any two of these will give a secondary color—orange, purple or green. Two colors are called complementary colors if the one is composed of two of the primary colors and the other one is the third primary color. Thus, green, composed of the primary colors blue and yellow, has as complementary color the third primary color; *i.e.*, red. Consulting the diagram it will be found that opposite colors are complementary colors; *i.e.*, blue and orange, red and green, yellow and purple. If two complementary colors are put alongside of one another, each color will look brighter alongside the other than if placed by itself; this is due to the law of contrasts. Thus, the same green if placed alongside red, will look greener than when by itself, and the same holds good for the

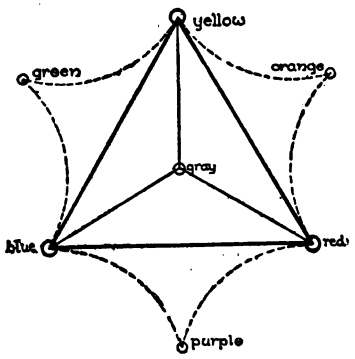


Fig. 21. Diagram of Colors.

red. If complementary colors are mixed together you get a softer color, a gray and sometimes muddy effect. If blue, red and yellow are mixed together in the right proportion a soft gray is obtained

Water Color Rendering. Where colors are used for architectural drawings they should be mixed fresh, if clear tints are wanted, but in places where it is desired to have certain effects obtained by allowing color to settle, tints that have stood some time may be used. Especially is this true for plans, where the color is allowed to settle in putting in grass, trees, statues, etc. When it is desired to let the color settle it is better to leave the board flat and carry the color along with the brush, leaving it until it is dry. Some draftsmen keep the board level for all their work.

Sketch elevations in pencil may be inked in or may be rendered directly in water color, the shadows being cast and various colored tints laid on to show the different materials, shadows, window openings, etc.

Sketches rendered in sepia only are very effective, putting in the lines with the pen, and rendering with light sepia washes. Elevations are usually most effective when the shadows are put in by washes that grade quickly from dark to light, brilliancy is thus obtained. It is astonishing what effects can be obtained with very faint washes. This applies especially to small scale drawings. The larger the scale of the building or detail, the stronger should be the coloring and values of light and dark.

When sections are colored the parts actually in section are outlined with a strong red line and tinted a very light pink. The colors on the wall are merely suggested.

On the plans the mosaic, furniture, etc., is often shown in a light pink. Where a statue has a prominent place it is put in in strong vermilion. Attention is called here to the fact that lettering on a plan counts as mosaic, and should be done in such a way that it will help the effect sought for, a very important point to remember in competition drawings.

The important thing to remember in rendering is to get the correct relative value of lights and darks. To do this it is necessary to have clearly in mind what the important features to be brought out are and what is the most direct way of accomplishing

this; in other words, the aim should be to make as harmonious a composition as taste, talent and thought can produce.

Water Color Sketching. Nothing is more useful to an architectural draftsman than out-of-door sketching in colors. A water color block should be his constant companion on his Saturday half holidays, and, if possible, he should join some sketching class.

The sketches in water color may be taken from natural scenery, but the student should also make studies and color sketches from color decorations of exterior and interior of buildings.

Do not indicate too much in water color sketching, search for the big masses in shape and color values and put them in direct and simple.

A draftsman who gives his leisure time to water color sketching in summer, and to evening classes in drawing from the antique and from life in winter, will have as good a training as could be wished for in this part of his architectural career.

PRELIMINARY STUDIES IN ARCHITECTURAL DESIGN.

Methods of Study. Different designers work up their drawings in individual ways. Good results are, as a rule, accomplished by getting ideas on paper, comparing and working up the best, and combining different features from the different sketches. Some men of the highest ability prefer to work in this way. Others work up the ideas in their minds before drawing them on paper, often not changing a line once it is put on paper. The latter proceeding is dangerous, as it tends to make the designer satisfied with the first idea that comes to his mind, and makes him unwilling to search for other ideas; he is liable to become narrow and careless.

Putting Ideas on Paper. The problem which the architect has to work out is to make the building of a form and of dimensions best suited to the demands of the client, so that all the parts are in good proportion and in harmony with each other. Much detail in former times was studied on the building in course of construction, but now everything has to be prepared beforehand, and the smallest details foreseen before the building is commenced. The preliminary sketches are generally made on a small scale, one-eighth inch, one-sixteenth inch, or one-thirty-second inch to the foot, worked up from rough thumb-nail sketches often not drawn to scale. Some design-

ers will work up their schemes upon the back of an envelope, and these can be brought into scale in the same proportion in which they are sketched out by means of the proportional dividers.

Architectural work is half way between mechanical drawing and so-called freehand drawing, permitting more freehand work than an engineer would consider proper, and demanding more line drawing than an artist would think of employing.

The most successful architectural design generally comes from numerous freehand sketches, as well as accurate studies, frequent erasing and changing on the original drawing, placing studies side by side and comparing them, until a satisfactory solution is found. It is only by continued practice that freedom of expression is obtained, and without this faculty, the best ideas are useless. The well-equipped architect carries a soft pencil, and sketches as rapidly as possible every new impression on paper.

Use of Tracing Paper. When the plan has been well studied, a sketch of the elevation and section should be made as a check on the "scale" of the plan. Tracing paper should be constantly used, both in making rough studies over the drawing and in making accurate line-drawings for comparison of the different schemes. These drawings on tracing paper as studies in proportion, should be as accurate as the finished drawing, though, of course, no care is necessary in giving them a finished appearance, and the straight lines may run across intersections, and erasures and changes may be made freely.

METHOD OF STARTING A PROBLEM AT THE ÉCOLE DES BEAUX ARTS, PARIS.

At the School of Fine Arts, in Paris, when a problem is given to the students, they are obliged to work one day by themselves getting out the scheme of the building. Each student then takes a tracing of his "sketch," leaving the original at the school. In his own "atelier" or drafting room, he works up the "sketch" with the criticism of his own professor and fellow students. At the end of four or six weeks the finished drawings are sent to the school to be exhibited and prizes or mentions awarded by the jury selected by the school. The preliminary work of the "sketch" is very similar to actual practice, because an architect is often obliged, in a very short time, to get out preliminary sketches for a client, and these

having been accepted, it is his duty to carry them out with as little change as possible, excepting to perfect the proportions and details.

Sketch Plans. The plans, even in the studies, should have the walls colored in with any appropriate color, such as dark gray, as otherwise it is very difficult to see on paper the proportion of the spaces, the ease of circulation, and the general character of the whole in mass and in detail.

Sketch Elevations. After the plans have been thoroughly studied the elevations may be worked up, studying the architectural style and general character of the exterior in relation to the plan. These drawings should be studied over and over again on tracing paper, casting the shadows so that the projection of cornices and sizes of window openings may be seen; at this time also details of a larger scale may be studied in sketch form.

On the elevations or in perspective, the jointing of the stone, brick or terra cotta, may be drawn and this will give a surface texture that may save further rendering.

Perspective Studies. For all smaller buildings, such as cottages, farm buildings and small public buildings, requiring a picturesque treatment, such as a broken roof line, it is better, instead of spending much time on elevations with the shadows cast, to draw almost at the start, a perspective from the most important point of view, and make rapid sketch perspectives from several different points of view.

Perspective Drawing. A perspective should be made of every building designed, primarily in order that the designer may see how planes at right angles—for instance, the side and front elevations—come together, and also how roof lines will look from the customary point of sight. This is especially necessary in buildings of a picturesque character. A perspective is also generally demanded for exhibition purposes, so that clients may gain a better idea of the appearance of the proposed building.

Perspective sketches to explain certain points in the drawings are of great value. Very difficult detail drawings may have sketched on them the details in perspective from different points of view. These sketches will explain more clearly than many careful drawings how certain parts come together. Such drawings are very welcome in the workshop and on the building in course of construction.

EXHIBITION DRAWINGS.

Exhibition or show drawings consist of plans, elevations, sections, and perspectives; the drawings are in line, pencil, pen and ink, or color; and all are carefully drawn and mounted, to show the scheme for the proposed building. These may be the preliminary sketches of an architect regularly employed, or they may be competition drawings.

The plan is blacked-in, the furniture delicately tinted, and the surroundings rendered in monotone or color. On the elevations the windows are colored in with graded washes. Every shadow is cast and tinted in; if in color, the different materials are indicated by different colors. In the sections shadows are cast on the section and the color schemes of the various apartments are suggested.

The general idea of the proposed building is best presented to the public by a perspective view, rendered in pencil, pen and ink or color. The perspective is generally laid out in the architect's office and then it is sent to a professional artist for completion.

SKETCHING.

We have considered drawings made on a drawing board with T-square and triangles. There is another way of drawing, that is, by sketching.

The sketch is the most rapid means of progressing in the art of designing. In sketching an object one examines it more closely than one otherwise would. Not only is it necessary to understand a composition, to distinguish its separate parts, but it is necessary to fix the relation of these parts and to study carefully the proportions. The eye alone is the real instrument for measurement and guide for proportion, and the sketch is the means for training the eye. Practice alone will give facility in sketching.

Do not make sketches primarily in order to collect material, but make them in order *to learn how to see.* Sketch books may be kept as souvenirs, but the profit from them will be more in the instruction gained while making the sketch than in the sketches themselves. Through abundant sketching a freedom in the expression of ideas is also gained.

The point to keep in view in sketching is to show the character of the subject attempted. The exact dimensions one can get only with

the tape-line, but the most carefully measured drawings often fail to show much character. A photograph is liable to represent a subject other than as the eye and hand see it. But if the effect of the subject, the impression of the beholder, can be reproduced in the sketch,

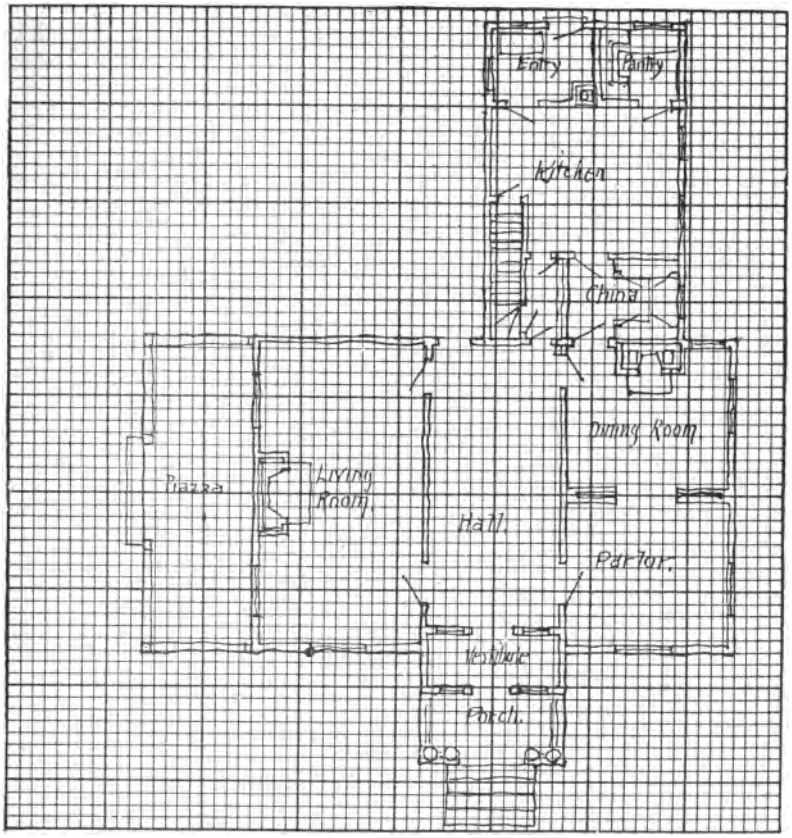


Fig. 22. Cross-Section Paper.

something has been obtained which the tape and the camera cannot hope to accomplish.

Materials for Sketching. At first it is a good idea to use cross-section paper, paper ruled in squares of $\frac{1}{4}$ in. or less, which makes it easier to draw at right angles; but from the moment that the draftsman is able to get along without these lines he should employ only blank paper. A small sketch book should be carried in the pocket. For small pencil sketches a smooth paper (metallic paper)

gives crisp effects, but much rubbing cannot be done. A gray paper gives good effects with pencil or color used as a medium, chalk or Chinese white giving the high lights.

The sketches can be made in pencil, charcoal, ink, crayon, or in colors; the medium of expression is of little importance, as, after having learned to see an object rightly, the drawing can be made, as Ruskin says, "with a stick of wood charred at the end." A sketch should be light and clear. Shadows may be cast, but merely to express the projections, and should be only lightly shaded in.

Subjects to Sketch. In almost every city there are small classes in freehand and charcoal drawing which the architectural student should, if possible, attend; and in connection with every art museum there are generally day and evening classes. But great progress may be made by individual work in drawing interesting objects. Do not commence with making a sketch of a whole building. Sketch individual features, like a doorway, some ornament, etc. Sketches of buildings or motives of buildings should be made in direct projection as well as in perspective. The sketches in perspective will help to explain the geometrical sketches and to teach the student to think in three dimensions.

A great deal can be learned by copying photographs of good work, but the greatest benefit is derived by drawing from nature. By the latter the student learns almost unconsciously the laws of perspective, form, and proportion, and above all learns to think "in the solid." It leads to the appreciation of the fact that architectural drawing is the expression of solids, and in order that these solids shall be successfully shown, the one that draws them has to see them in his mind's eye as they actually are going to appear when built.

He should be very careful in the selection of his models to draw from, and choose only such that are beautiful. Too often the student is told to draw no matter what, under the pretext that it is always an exercise. Without doubt it is difficult to draw any model at first exactly, but what does it amount to if he occupies his time with copying those things which do not stimulate and develop his sense of beauty. There is no better practice than to draw a flower, a leaf; and if he has access to museums, etc., he should draw from the antique models, sculpture, and ornamental subjects. By drawing

the latter he can learn besides how in olden times natural objects were conventionalized for use in decoration.

Memory sketches are excellent practice. Go to see a model, study it as carefully as possible; then go home and make a sketch of it. The student may be sure that his memory will betray him, and he should go back to the subject and study it again and again—twice or three times if necessary—after which he will finally arrive at a reasonably accurate sketch.

MEASURED WORK.

There are two occasions for making measurements of old buildings; one, when it is proposed to make alterations; the other, for the sake of study, making drawings of portions either for immediate study or future reference.

Materials. It is a good plan if possible to take a small drawing board, T-square, and triangles to the building. Cross-section paper ruled one-eighth inch between light lines and one inch between heavy lines is very convenient. See illustration, Fig. 22, showing use of cross-section paper. Drawings may be laid out directly to scale on this paper, at one-eighth, one-quarter, or one-sixteenth inch to the foot, or details drawn at three-quarters inch to the foot, or full size.

Measuring Tapes. The dimensions should be taken with a tape, and for architectural work a "metallic" tape or cloth reinforced with fine wires and having clear figures, is very satisfactory, though it will be advisable to use a steel tape for very accurate work.

Datum Lines. As a general rule, it is best in frame buildings to take the horizontal measurements on the sill line, making a small section to show the relation of the sill to the walls. In brick and stone buildings they should be taken on the outside wall face or ashlar line. For heights, the finished floor levels should be taken as starting points, the main first floor of the building being the general datum. If there are many projections in plan it will be well to draw a straight base line and measure it from this line. If old buildings are out of level it will be necessary to use a straight edge or draw a level line on the wall and measure up and down from this level.

Hand Level. The hand level will be found very convenient for obtaining approximately the grades about the building. This

is a small instrument used by railroad engineers in working out the elevations on each side of the track. The level can be also obtained by looking toward the horizon, pulling down the hat brim until the point coincides with it, turning on the heel carry the horizon level to the direction desired. This will give a point at the level with the eye.

Elevation Measurements. Total distances should be taken, and interior heights from floor to floor (with thickness of floors) should be run from basement floor to top of roof, and if possible a line should be dropped down the outside of the building to check this. It is well to mark size of glass, and give outside dimensions of sashes,

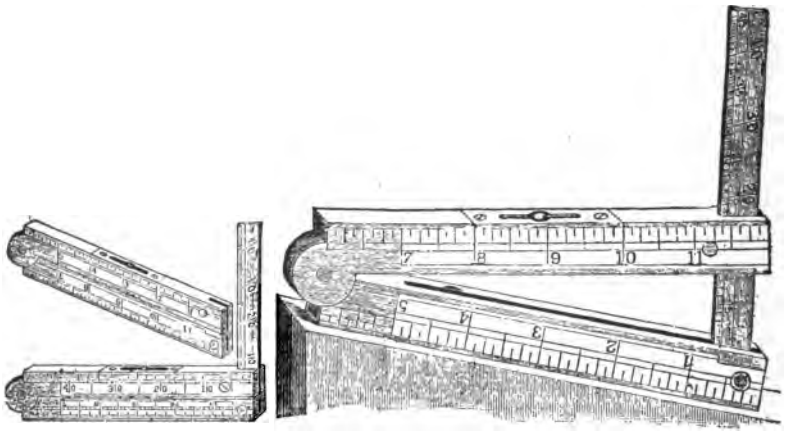


Fig. 23. Twelve-inch Single Jointed Rule and Level.

taking dimensions to centers of windows or edges of stone or brick openings. Measurements are given by some architects from frame to glass openings. Sketches or details should be made of typical windows, and variations from the type. Roof pitches may be obtained by a level and measuring the rise per foot, or outside dimensions and total rise may be taken. A convenient instrument for doing this work is a twelve-inch single-jointed rule and level, shown in Fig. 23.

Arches. In measuring arches, the height A, Fig. 24, from the ground to the spring of the arch should be given, the total height B, and the width C. The curve is obtained by giving the length of the rdii or by laying a straight edge, D F, against the curve and measur-

ing the distance D E, which will locate one point in the curve. Other points may be taken by offsets from the straight edge.

Projections. Projections are obtained by measuring in from a plumb line. The diameter of columns may be ascertained by means of two parallel straight edges or by dividing the circumference by 3.1416.

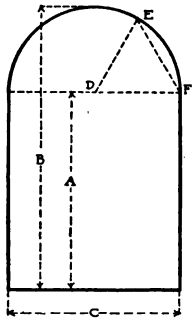
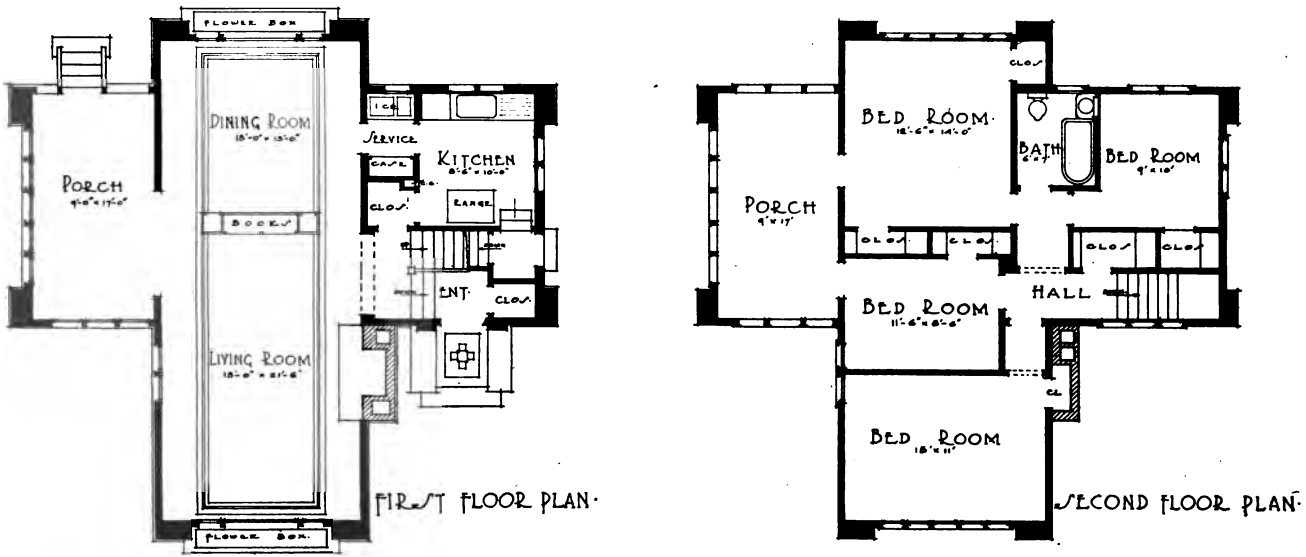


Fig. 24. Measurement of Arches.

Inaccessible Portions. In places where it is impossible to reach the point it is desired to measure there are several ways of obtaining the dimensions with considerable accuracy. A photograph should always be taken of the building measured, and a proportional scale can be made from the known dimensions, which can be used on the photograph for determining unknown dimensions.

Approximations. In brick, stone, clapboarded or shingled buildings the different courses may be counted and the totals figured from those that can be measured. Where rapid memorandum sketches are made distances may be easily obtained by pacing, some men taking nearly a three-foot pace, others walking easily five feet in two steps. In this case every other step is counted as five feet. The total heights may be obtained by measuring up as high as can be reached, then standing at a distance, holding a pencil at this known height, measuring the distance by the eye to the top of the building. Or, a man's height can be taken to gauge the approximate height. The foot rule may be held up at such a distance from the eye that every quarter inch corresponds to a foot on the building, and the dimensions can be read off in this way.

Rubbings. Rubbings may be taken of tablets, lettering and flat ornaments by laying paper on the ornament and rubbing over it with a shoemakers' heel ball. The pattern cut in will be left white and the rest of the surface will be blackened by the heel ball.



FLOOR PLANS OF WILLIAM V. CARROLL RESIDENCE, OAK PARK, ILLINOIS

Tallmadge and Watson, Architects, Chicago

For exterior views see opposite page 131, Vol. III

ARCHITECTURAL DRAWING

PART II

PRACTICAL PROBLEMS IN DESIGN

NOTES ON THEORY OF DESIGN

Composition. It is impossible to formulate laws of composition which, even if faithfully observed, will absolutely insure satisfactory results. That is to say, any work of art—such as a picture, a statue, or a building—may comply with all the general laws of composition and still not be really artistic.

A great deal depends on the feeling of the designer. A carpenter may make a cornice for the exterior of a house, or a mantel-piece for the interior, without having been taught any of the formal laws of composition; and nevertheless, by careful study and through the desire to build something pleasing, may produce something much more artistic than the most carefully wrought effort of a designer who knows all these so-called laws but lacks all artistic feeling.

Workmen in the various trades can assist the architect materially in producing an artistic result. One of the most desirable characteristics in a workman is that he shall execute the wishes of the owner as expressed in the architect's drawings, and carry them out as artistically as possible in every detail. There is a certain character in every piece of work which every workman should try to understand and carry out in a simple, frank, decisive, and straightforward way. Every workman feels the value of truthfulness in work, and objects to sham in doing good work.

Turner, the great English painter, was a man who did everything that he had to do, no matter how trivial, well. John Ruskin says of him, in his lectures on architecture and painting:

"He took a poor price that he might live; but he made noble drawings that he might learn. He never let a drawing leave his hands without having made a step in advance and having done better in it than he had ever done before."

Composition is the art of bringing together various interesting details, so that the whole result will be harmonious and pleasing.

The important features should be on axes, or grouped symmetrically on either side of an imaginary center line. For instance, in a room, if the fire place is to be one of the features, it should be centered on one of the axes of the room. The remaining features should be arranged with relation to the axes or center lines of the room so that as a mass they will balance each other.

In a good composition some single feature should dominate—for example, in a building, the main gable, or a tower, or a long, simple roof line; or in a room, the fireplace or a painting; etc. In decorating a house, the general effect should be pleasing, and should not be too much broken up by spotted details. There must not be too many equally interesting points; otherwise the result is either monotony or competition; one point must dominate. There must not, for example, be other gables competing with the main gable by being too near the size of the main gable. For the same reason it is better to group windows and other features in odd numbers and accent the central one.

It is well to think of the location of the different interesting points. In a cottage—to take an example—the gable that is seen from the best point of view should be near the center of the perspective; or, again, a tower should not be isolated or appear so much at one side from the best point of view that it will look as if disconnected from the house.

The smaller parts of the composition should have a proper relation to the main motive. The dormers, for instance, in a cottage, should be in the same style as the main gable, or in harmony with the style.

Nevertheless, all these different parts must be used so that there will be some contrast, in order to give life and interest to the composition. No detail from a different style, however, should be brought in without the designer being sure that the harmony of the composition is not thereby disturbed. To learn how to compose, it is not sufficient to study books and receive instruction in the school or in the drafting room; the student must supplement this with the study of nature and of objects and buildings themselves.

Scale. The word "scale" has been used to designate a measure of distance—for example, a scale of one-quarter of an inch to a foot.

"Scale" is used also in another sense—that is, to designate the appearance of a building or any artistic composition, which, without

considering the actual dimensions, gives us an idea of the size. For example, in the two sketches A and B (Fig. 25) the two vases have the same proportion; but one is a huge decorative vase standing at the side of a fireplace, while the other is a small vase standing on a table.

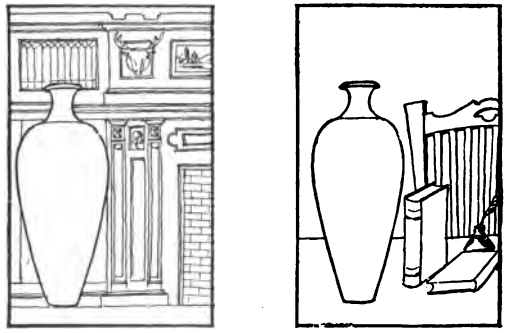


Fig. 25.

It requires the books and other details of well known dimensions to suggest the small scale of the one, and the mantel-piece to suggest the scale of the other. The same principle is seen in doors and windows, in the effect of steps in front of a building, in balustrades, and in all details with which we are familiar in our daily life.

A drawing is "large in scale" when it appears to be drawn at a larger scale than has been really used; for example, a drawing of a building might look as if it were laid out at quarter-inch scale when it was really laid out at one-eighth-inch scale. If such a building were erected, it would be much larger than the drawing would indicate. On the other hand, if it is "small in scale," the details are too small and the building will appear as if it were built for dwarfs.

The materials used in construction affect the scale of a building—such as sizes of brick, stone, clapboards, etc. Arches span larger spaces than lintels; iron construction needs fewer supports than stone construction. The detail should be somewhat larger in scale in the upper part of a building, where it is seen from the ground, from what it is in the lower portion near the observer. Interior detail should be finer and smaller than exterior detail.

Statuary, when called "life-size," is actually made about one-quarter of the height larger than life size. The reason for this is that objects in the open air, or in large spaces, look smaller than they

actually are. The size also depends largely on the height from the ground.

If a building does not appear to be in good scale—that is, if the drawing does not suggest the actual size of the building (which may be tested by sketching in a figure of a man, and measuring to see if the house is in scale or not), the detail should be studied to see that it is not too large or too small; other details may be added, such as steps or balustrades; or, if the design is an interior, the walls may be decorated with natural objects in the right scale. Anything that will suggest the height of the human figure may be used, or stone joints and other suggestions of material may be made more evident.

Ornament. Architectural ornament is the decorative treatment of architectural motives on a building. The ornament should be carefully studied on the small-scale designs, and worked up from these to the working drawings.

All ornamentation or decoration should be drawn out on each design, and particularly on the small-scale drawings, even if it is to be carried out by other designers, modelers, or decorators; for it should be remembered that the one man who is to bring together into a single composition all the elements of a design, is the Architect. The decoration, whether sculptured or painted, is executed either from scale details or full-size drawings, by the decorator or sculptor. If any change is made from the main lines of the design, this change should be studied on the small-scale drawings; otherwise it may be found that the detail is entirely out of scale with the general architectural lines.

It should be clearly understood that loading a building, a mantel, a cornice, or any motive with ornament does not make it a work of art. Everything depends on where and how the ornament is applied. Besides, generally, any motive is more artistic if it is perfectly simple.

Criticism. All through the work of design, it is of greatest advantage if criticism can be obtained from other architects and draftsmen; and even the criticism of outsiders, conscientiously made, will frequently suggest valuable improvements in design. Whenever an intelligent criticism is received which suggests a change, it should be a matter of principle with every designer to make a sketch embodying this change, in order to see whether or not the criticism is good.

DESIGN OF THE DWELLING

The plan of the modern residence began to be worked out in the 18th century. There is a treatise on architecture published at that time by Blondel, who says that a complete reformation had been made in the architecture of large and small dwellings from the point of view principally of the arrangement of rooms; great efforts had been made to substitute for the long, rambling succession of single rooms, an arrangement of rooms double in depth, with separate communications so indispensable for conveniences in a building.

It became clear that in a dwelling the ease of circulation was very important, and that the approaches to and exits from the various parts had to be well worked out, for the living rooms as well as for the service rooms. The aim of architects in the 18th century was for *independence* in the house, and it is to this that we owe their very remarkable plans.

The treatise on architecture by Blondel contains many interesting plans, well worthy of careful study. On the subject of Room, in particular, Blondel gives some interesting data:

"It seems", he says, "that within about fifty years French architects have, in this respect, invented a new art. Before this, our edifices in France, in imitation of those of Italy, had an exterior decoration which made a very beautiful architecture; but the interiors were hardly livable. The architects seem to have tried to keep out the light; one could hardly find a place for a bed and for the principal articles of furniture. The fireplace occupied the largest part of the rooms, and the smallness of the doors gave an inadequate idea of the places to which they gave entrance .... The arrangement should be the first object of the architect; decoration depends absolutely on a well-studied plan. It is the arrangement which establishes the length or width and the height of a building."

Number of Rooms. The great objection to many small houses is that the people want the same number of rooms for a small amount of money that others have where more money has been spent. A desire to have six rooms and a bath often results in making all the rooms tiny and uncomfortable—more like boxes than living, habitable spaces. These houses are not necessarily cozy just because they are small; a cozy corner in a big room has much more of the cozy feeling than is found in the small rooms of an apartment. There should be one good-sized room in every house or apartment, even though one room has to be sacrificed.

Hallway. The hallway should be neither a cramped, narrow

space, nor arranged in such a way that it will be a draughty part of the house. It should be borne in mind that if open from first floor to roof, the heat will pass up the hallway; for that reason it should be sufficiently closed off from the other rooms. It may be arranged as a comfortable gathering place for the family. Indeed, with the staircase kept properly to one side, and with a large fireplace the hallway may form the central room of the whole house.

Stairways. Some men say that they build a house around a bathroom, because they consider that the most important room in the house. Next in importance is the staircase. The front staircase should be easy and large. A 7 to 7¼-inch rise, with 10 to 10½-inch width of tread, is customary, though a 6½-inch rise with an 11-inch tread is easier and looks much better. Staircases, in the better class of house, may be as easy as 6-inch rise by 14-inch tread, or even 5½-inch rise with 15-inch tread. In back staircases a 7-inch rise with 9-inch tread is not too steep; and they are frequently found as steep as 8-inch tread. If space allows, the rear staircase should be sufficiently wide to take up trunks and furniture—say 3½ to 4 feet, with wide doors (3 feet 3 inches) opening into it. In this case the stairs should be strongly supported. Staircases may be made fire-resisting by stopping the space between the stringers with brick and by covering the underside or soffit with metal lath.

Proportion of Stair Riser to Tread. A good formula to use in laying out a stairway is as follows: Let R = the rise and T = the tread, then

$$2\,R + T = 25.$$

i. e., twice the height of the riser plus the width of the tread should equal 25 inches.

Living Rooms. The living room, library, parlor, reception room, should all be "livable." The shut-up "best room" is a thing of the past.

Sitting Room. This should have a southerly exposure, so that it will be sunny and cheerful all the time.

The best arrangement for a sitting room is with the fireplace at one end, the windows on the long side, and the entrance at the further corner. The next best arrangement is with the fireplace on the same side of the room as the entrance, and both on the long side of the room. The most unsatisfactory arrangement is to have the door

on the wall opposite the fireplace or close by the fireplace, where there is a constant draft.

The room should express comfort and restfulness. There should be no feeling of over-decoration, and nothing in the room should be so striking as to be the first and only thing to be seen. The great objection to so-called "decoration", is that each decorator or designer thinks only of his own work, consequently making it prominent; and it is extremely difficult to make the decorative elements harmonize.

Dining Room. The dining room should be, as a rule, on the side of the house toward the morning sun. It should be cool in summer and warm in winter, as it is the one room that is necessarily occupied at least three times a day. A westerly outlook is generally disagreeable on account of the low-lying sun for the evening meal.

Butler's Pantry. The butler's pantry should have an outside window, and doors leading into the dining room and kitchen. Sometimes a slide is put in, opening into a small china closet in the dining room. The butler's pantry should be quite large. The story is told, of an architect who dined with his client several times while he was making the sketches; and each time, on his return to his office, he enlarged the butler's pantry, and when the building was erected it was still one of the cramped rooms in the house.

Kitchen. The kitchen should not be placed in too close proximity to the living rooms, and should be on the northwest corner of the house. As a rule, it should be separated from the living parts of the house by at least two doors. This is done, partly on account of the odors from the cooking, and also because of the heat. A basement kitchen is objectionable on this account. The kitchen should be thoroughly ventilated, the windows being set high—as near the ceiling as possible —to let out the hot air, the sill being located above the backs of the tables and sinks. A hood over the range connecting with a ventilating flue, is very useful for ventilating. This ventilating flue will be either a space around the flue from the kitchen range, which will be constantly warm; or it may be a separate, square flue next the smoke flue in the chimney. It is advisable sometimes to put deafening felt over the kitchen, so as to prevent the passage of sound and heat if there are sleeping rooms above.

Refrigerator. The refrigerator should be located so that it will be easily accessible from the outside, for putting in ice; and it should

be near the kitchen without being too near the range. The refrigerator drip should never connect directly with the sewer but should have a separate pipe leading to a dry well outside the building. The simplest and cleanest way to trap this is as follows: Build a galvanized-iron pan large enough to rest on the floor under the drip-pipe of the refrigerator; and carry lead pipe from this down into the cellar, ending in an ordinary milk jar which stands in another galvanized-iron drip-pan connecting with the dry well.

Storeroom. The storeroom may be made rat-proof by plastering on metal instead of wooden lath, and by plastering the ceiling underneath with the same lathing, taking the precaution to cover all openings.

Bathroom. The bathroom may have tile floor and walls, or, for ordinary work, a Georgia pine floor, with North Carolina pine sheathing four feet above the floor. A sanitary base—that is, one rounded to avoid a corner between the wall and the floor, such as is used in hospitals and in many schoolhouses, may be used. Waterproof paper should be put in between the upper and the under floor in the bathroom, being connected by lead flashing with the outside of the building. This will prevent damage in the case of an unexpected overflow.

Lavatory. A lavatory on the first floor is very convenient. This may open from the hall or be connected with a coat closet. It should have a window.

Closets. The closet doors should open in such a way that the light from the window shines into the closet.

On the sleeping-room floor, a housemaid's closet may be provided—if possible with an outside window. This closet should contain a galvanized -iron or enameled-iron sink, provided with a flushing tank as well as with hot and cold water faucets.

The linen closet should preferably have no drawers, as they furnish hiding places for mice. Shelves will answer every purpose.

Bicycle and dark rooms, play room, sewing room, billiard room, music room, den, conservatory, etc., should also be considered.

Cellar. The cellar should be well drained, if possible, with a drain-pipe separate from the soil-pipe. There should be a blind drain under the wall, and the wall should be damp-proofed in damp locations, by the use of layers of slate stone extending through the wall at the surface of the ground, or layers of well-tarred paper at this point.

Waterproof cellars are made by putting down several layers of tarred paper well mopped with hot tar or asphalt, on which the concrete cellar floor is laid. As a rule, however, it is best to have the cellar connected either with the soil-pipe or with the blind drain, and to have all the concreting put in so that it will slope to one point, where will be placed a trap with grating.

VARIOUS STAGES IN BUILDING A HOUSE

The point where the majority of people, who know nothing about architecture, come in contact with the architect, is when they make up their minds to build houses of their own.

To develop this point more clearly, let us consider the situation that arises when a business man wishes to build.

The problem, as it comes to most men, is a question of number of rooms needed, amount of money available, and proposed location of house.

Let us say that Mr. Smith, after lookng at various lots and making as many inquiries as possible through friends and acquaintances, and having also gone to some real estate agent who deals largely in land in such locations as he considers desirable, has obtained an option on, or possibly has purchased, a lot, the price being, say, $800. He has available $2,000, besides the money he has set aside for furnishing the house and paying the architect's fee. He is willing to give a mortgage on the house for, say, $3,000. Taking $4,600 as the value of his proposed house would leave him a margin of $400. Accordingly, he goes to an architect who, he he thinks, will plan his house satisfactorily, and tells him the circumstances, the requirements, and the amount of money available. A visit is made to the lot, to get the points of view, etc., and preliminary sketches are made.

Sketches. From the architect's point of view, the sketch period is vital in respect to the success or failure of the house. It is at this time that he becomes acquainted with the owner's ideas and does his best to interpret them properly so that there will be no criticism or feeling of disappointment on the part of the owner—in other words, so that the house will harmonize completely with its owner's habits and tastes.

Every man has certain hobbies and independent wishes in regard

to his house; these the architect should study and give the proper expression.

In regard to the practical use of the house, every member of the family, should be thought of and consulted. The architect should obtain a careful outline of the requirements from the owner, going over the number of rooms, size of rooms, comparing them with rooms already known to the owner, heights of stories, location and exposure of rooms, for the view, etc.

After sufficient data have been procured to make a complete schedule, several different plans of the proposed house may be sketched out at a small scale. Co-ordinate or section paper is very useful in sketching out different schemes. As a general rule, it is better for the architect to work out with great care some one plan which he considers the most satisfactory. In dealing with some clients, it is sometimes better to show this plan only; in the case of other clients, it is better to show them all the studies and consult with them about details that would be merely wearisome to other men. The sketches are generally laid out to the scale of one-eighth inch to the foot, though small "thumb-nail" sketches are frequently made at no scale, or sometimes several different schemes at a scale of one-sixteenth inch to the foot. Memoranda should be kept of all conversations with the client, for use in completing plans and in writing specifications.

Working Drawings. After the sketches are approved, the working drawings can be started. They are sometimes called "contract drawings," meaning the scale drawings accompanying the specifications and contract, though contract drawings really include the details, which are not generally made at the time the contract is signed. The character of these drawings has changed very much, even in the last few years, an astonishing amount of detail being put into the working drawings, while the architectural drawings of the English and Italian Renaissance show that the old masters must have studied much of their detail while the building was being erected. The main purpose of the working drawings is to give complete information of the building to be erected, as far as size and form can be expressed in projection, quality and general description being left to the specification. It is of considerable importance to put on a single drawing as much as

can be clearly expressed, since workmen generally are not inclined or able to gather information from several different drawings.

The working drawings are laid out at quarter-inch scale,* *i.e.* one-quarter inch equals one foot, with details at a scale of three-quarter inch to the foot, accompanied with full-size details. This is the customary scale in America. In England and also in some American offices, the rule is to make the working drawings at a scale of one-eighth inch to the foot, with details at a scale of one-half inch to the foot.

Plans of every floor, including basement and roof, all the elevations, and such sections as may be necessary to explain the construction, are required. In the sections, the vertical dimensions should be figured from finished floors.

Besides these drawings, a block or ground plan is frequently given, generally at $\frac{1}{16}$ or $\frac{1}{32}$ inch to the foot, to show adjacent walls, gardens, etc., and layout of grounds, location of drains, dry wells, cesspool, and water supply.

Separate plans may be given in procuring estimates for heating, ventilating, plumbing, and gas and electric lighting. These should be made subject to changes that may be proposed by the successful bidder, and, with these changes, should be presented by him to the architect for approval before finally going ahead with the work. This method is followed, because a guarantee is expected from the contractor for the successful operation of his work; and each contractor in the trades mentioned is likely to have good methods of his own, which he should be allowed to use. Sometimes all of these drawings may be incorporated in the general drawings.

Full-Size Details. Mouldings, and special parts of exterior and interior finish, such as base-courses, water-table, belts, cornices, capitals, special arrangement of brickwork, panels, carving, window-casings, mantels, stair-newels, balusters, etc., are drawn full size; carefully drawn sections are made full size. "Key drawings" at small scale, isometrics, and freehand perspectives are invaluable aids if drawn on the full size drawings. For cast iron and terra-cotta, allowance is sometimes made for shrinkage. This should preferably be left to the pattern-maker.

*NOTE:—There is a great difference between "quarter-inch scale" (*i.e.*, ¼ inch = 1 foot) and "quarter scale," or one-quarter of full size (*i.e.*, 3 inches — 1 foot).

Besides the contract drawings and subsequent detail drawings, other drawings are frequently called for, for which allowances have been made in the contract, as for furniture, special finish, etc.

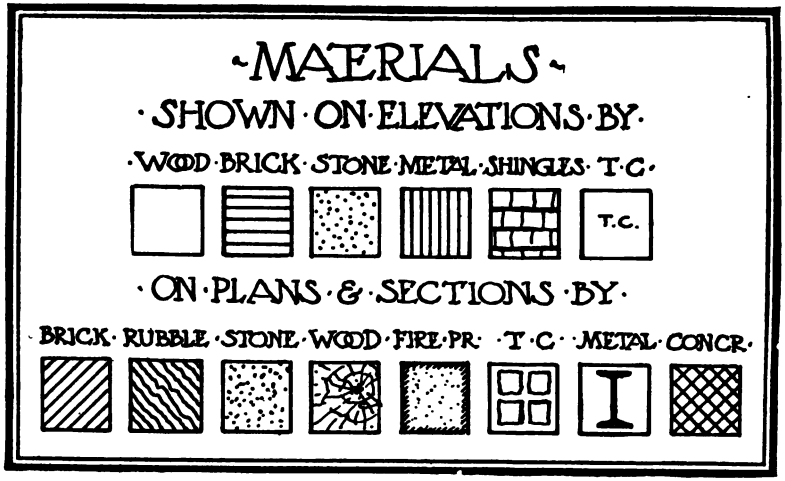

MATERIALS
SHOWN ON ELEVATIONS BY
WOOD BRICK STONE METAL SHINGLES T.C.
T.C.
ON PLANS & SECTIONS BY
BRICK RUBBLE STONE WOOD FIRE PR. T.C. METAL CONCR.

Fig. 26.

Representation of Materials. This may be either by blacking in, hatching, etc., or by use of colors. The former method (Fig. 26) is convenient for tracings to be blue-printed, as it saves coloring the prints.

On elevations, materials are shown as follows:

Wood	white.
Brick	horizontal lines.
Stone	dotted.
Metal	vertical lines.
Shingles	sketched to scale.
Terra-cotta, etc.	abbreviations marked "T.C.", etc

On plans and sections:

Brick	diagonal hatching, ruled lines.
Rubble	diagonal hatching, wavy lines.
Stone	dotted.
Wood	grain indicated, or black if small-scale.
Fireproofing	hatched margin, dotted surface.
Terra-cotta	divisions to suggest material.
Metal	steel sections suggested.
Concrete	cross-hatched.
Old work	white.

If colors are preferred, the following may be used:

Brass and copper.....yellow.
Brick.....light red.
Concrete.....Payne's grey, mottled.
Glass.....new blue.
Glass in elevations.....a graded wash of India ink, indigo, new blue with a little carmine.
Old work.....grey or black.
Plaster.....Payne's grey.
Sections.....construction not determined, pink with red border line.
Shadow in elevation....India ink with indigo or gallstone.
Slate.....indigo.
Steel and iron.....Prussian blue.
Stone.....raw umber or new blue, or Payne's grey.
Terra-cotta.....burnt umber.
Tiling.....light red with yellow.
Wood.....yellow ochre.

Coloring may be carried further, following this scheme, always placing guide-squares in one corner of the drawing with the names of the materials represented.

Tracing and Blue-Printing. Drawings of which several copies are needed, may be traced on transparent paper or linen, or laid out directly on these materials. Thin bond paper is often used. Prints may be taken from these, either blue or brown prints, giving white lines on a blue or brown ground, or by first taking negatives, dark lines on a white ground.

Notes should be kept for the specifications while drawings are being made.

Letting the Contract. When the working drawings and specifications are finished, owner and architect decide on three or four builders, any one of whom would be satisfactory, who are asked to submit estimates. The builders are allowed time enough to go over the plans and specifications carefully so that they may know the actual value of the work; and bids are sent in to the architect's office to be opened on a certain day, when the owner meets the successful bidder and a contract is signed for building the house.

In France there is generally a separate contractor for each kind of work; in England a general contractor makes up his bid from quantities given him by a quantity-surveyor; in America usually the sub-bids are given to a general contractor who takes the responsibility for the whole work.

The work generally starts immediately on the signing of the contract, and is carried on continuously, with visits from the owner and from the architect, payments being made at regular intervals or on completion of certain parts of the work.

During the progress of building, the owner and architect select fixtures, wall papers, etc.

BUILDINGS FOR OFFICES

The plan must be laid out so as to obtain the largest possible amount of space available; it must be made with reference to the constructive requirements.

Arrange the offices so as to take advantage of surroundings and light. A good outlook makes an office more desirable.

Staircases, elevators, piers, etc., should be arranged so that the actual renting space will be an open loft, where offices and windows can be divided up easily to suit different tenants, and can be easily changed.

Make the street entrance and corridors so that the offices can be easily reached and doors and signs easily seen. The corridors should not be less than 3 feet 8 inches wide; as a general rule, they should be 4 feet to 8 feet wide, depending upon the use, the number of offices and the size of the building.

Arrange janitor's and superintendent's offices, telephone, telegraph, news booths, and elevators so that the tenants and public may be quickly accommodated.

As a rule, unless there are two frequently used entrances, the elevators should be placed so that they can all be seen by a person entering the building.

A car 5 feet 3 inches by 6 feet, with a door on the long side and the rest of the side removable, is convenient for handling ordinary office furniture. One elevator in the building should be as large as this. Other elevators may be smaller.

If a building is more than 6 stories high, it is advisable to have one or more elevators express to the 6th story. The doors at the lowest floor, where the largest number of passengers pass in and out, and where there is generally a "starter" to see that the cars are not overcrowded, may be arranged so that the whole side of the car will open, allowing all the passengers in the elevator to pass out at once.

Staircases are rarely used in an office building. A width of 3 feet 3 inches is generally sufficient; and sometimes staircases are as small as 2 feet 9 inches.

If there is a light court, it should be of such shape and location as to receive as much sun as possible.

There should be toilet rooms on every floor; generally lavatories are placed in the separate offices. Radiators are put in front of each window, transoms over every door; the lighting is done by electricity with drop-lights and receptacles for desk-lights.

Write the specifications so that the building may be economically constructed and will be a paying investment, and yet not so cheaply built that it will be unattractive or constantly needing repairs.

PRACTICAL EXAMPLE: A COLONIAL HOUSE

Conditions. A business man, having purchased a lot sufficiently large to give him space on all sides, wishes to build a colonial house containing nine rooms.

On the first floor, a hall is to be in the center, with vestibule and porch in front and doorway at the rear, so that the air may circulate freely in the summer time. The hall is to be about 15 feet wide. At the front, on the left, opening off this hall, the owner wishes to have a large room about 14 feet by 25 feet. The parlor and dining room are to be about 14 feet by 12 feet each. On the right of the hall, next to the dining room, is to be a china closet, with shelves and drawers, connecting with the kitchen. Beyond the kitchen is to be a pantry, with shelves, cupboards, and cases of drawers. The back entry is to have a place for a refrigerator. The rear door of the front hall is to open on an ample porch, where the family may sit.

The second floor is to have four bedrooms and an alcove in the main part of the house, a convenient bathroom and bedroom in the rear, and suitable linen closets. There are to be a front stairway and a compact back stairway. The attic is to be arranged for sleeping rooms.

Sketches. The drawings first to be made are sketches at a scale of one-eighth inch to the foot, drawn on Whatman's paper, with the plans inked in and the walls shown black. The elevations may be sketched in pencil, merely the front and left-side elevations being shown.

Figs. 28 to 42 show complete working plans of a house fulfilling these conditions—a three-storied frame residence, such as is frequently constructed in our suburban country towns and smaller cities. The drawings include the basement, first floor, second floor, attic, and roof plans, front elevation, and one side elevation, corresponding framing plans, and details of different parts of the house. Details are not always included in the contract drawings, but are made as the work progresses. The rear elevation and one side elevation have been omitted, as they are of the same character as those shown. These plans are usually drawn at the scale of one-quarter inch to the foot; in the illustrations, they are reduced.

Plans. On commencing the quarter-scale, the principal dimensions should be given in feet and inches, not in fractions of an inch, to the outside line of the sill. The main contour lines should be marked first, and then the wall should be shown on the first floor, six inches thick. The sill line is shown on Fig. 29, one inch inside of the outer wall line, and is merely drawn in a little way at the corner of the building. In drawing out the plans in pencil, the lines may be run straight through, taking no notice of openings. The lines that run over can easily be erased later. In commencing to lay out the plan, it is well to draw the center lines or axes first, as all the symmetrical points of the building will be laid out from these axes. Doors and windows either center on an axis, or, as a rule, are equidistant. The bay windows and chimneys are also located if possible on the axis lines. The door and window openings in the exterior walls are not located in plan until the elevations are laid out. When this is done, the sizes of window designed on the elevation can be transferred to the plan. As mentioned previously, in working over the plans, notes should be made for the specifications and marked on the plans; for example—*g. p.* (glass panel); *c. w.* (casement window); *t. l.* (top light or transom light).

Elevations. In laying out the front elevation, the center line should be sketched in sharply, in pencil; and the location of the sill line should be marked at the right and left of this center line. Then the outside finished building line should be drawn one inch outside the sill line, this being the outside of the boarding.

Useful Memoranda. In laying out plans at one-quarter of an inch to the foot, the beginner is often puzzled to know the simplest way

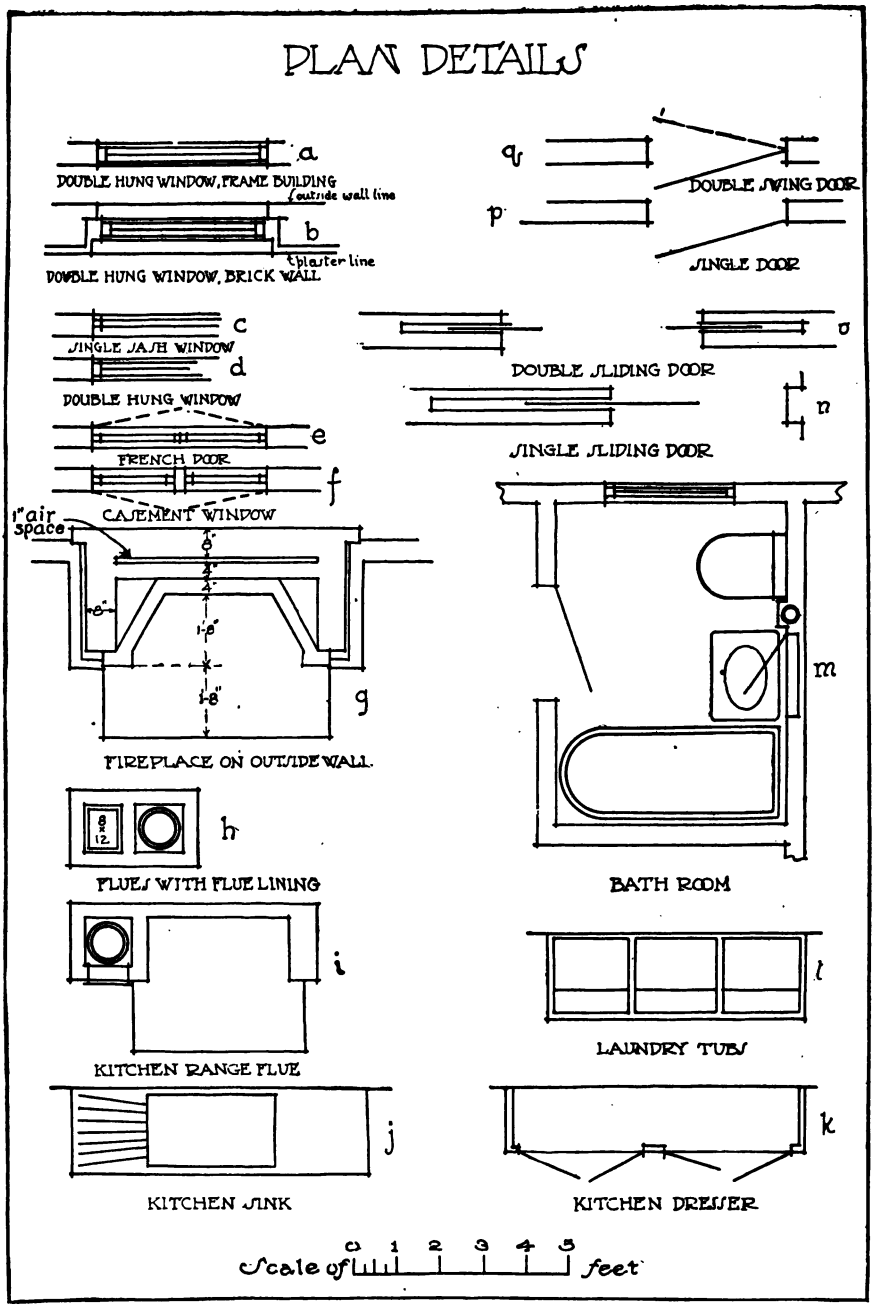


Fig. 27. Enlarged Details of Architectural Features of Colonial Residence

to show ordinary constructive forms; and in tracing plans, which a beginner is likely to be called upon to do, if the original is not very distinct, he will find it useful to have some guide for convenient reference—as, for example, that shown in Fig. 27. The lines in the drawing (*a*) of double-hung windows can all be laid to scale, though very simply expressed. The sill is shown, both outside and inside; and also the sash opening and glass opening. In a brick building, the brickwork and wood furring are shown (*b*). The distinction between single-sash (*c*) and double-hung windows (*d*) will be found convenient. The distinction between a casement window (*f*) and a French window (*e*) is not shown in plan, as the difference lies principally in the fact that the French window is carried to the floor. The casement window, on the other hand, is, in general, slightly different in having a mullion in the center for each sash to strike on. The French window is shown opening out, and the casement window opening in; but these could be made to open either way, and the casement window could be built singly, or in pairs, or in series.

In placing a fireplace (*g*) on the outside wall, an air space should always be left to prevent unnecessary cooling of the flues. The finished brick fireplace should be distinguished from the rough chimney; and, where necessary, flue linings should be shown. A space should be shown separating the furring from the brickwork at least one inch, as prescribed in all good building laws. This applies also to fireplaces on inside walls. The hearth is shown, either the width of the finished fireplace, or sometimes the width of the chimney-breast, and projecting 16, 18, 20 inches, or more into the room.

If the kitchen range is to be brick-set, a similar hearth and chimney-breast must be built (*i*); and in all cases it is advisable to have the kitchen duct circular (*h*), set in a rectangular flue which it keeps warm and which is available for ventilating the kitchen through a register set near the kitchen ceiling. The kitchen sink (*j*) should always be shown with drip-board. A kitchen or pantry dresser (*k*) should be shown with doors opening out—not sliding, unless the space is very limited. Laundry tubs (*l*) should be shown as indicated in the drawing. A bath-tub is indicated as shown (*m*), and other toilet fixtures are indicated similarly. Single (*n*) and double (*o*) sliding doors (inside), single doors (*p*) and double swing doors (*q*) are indicated as shown.

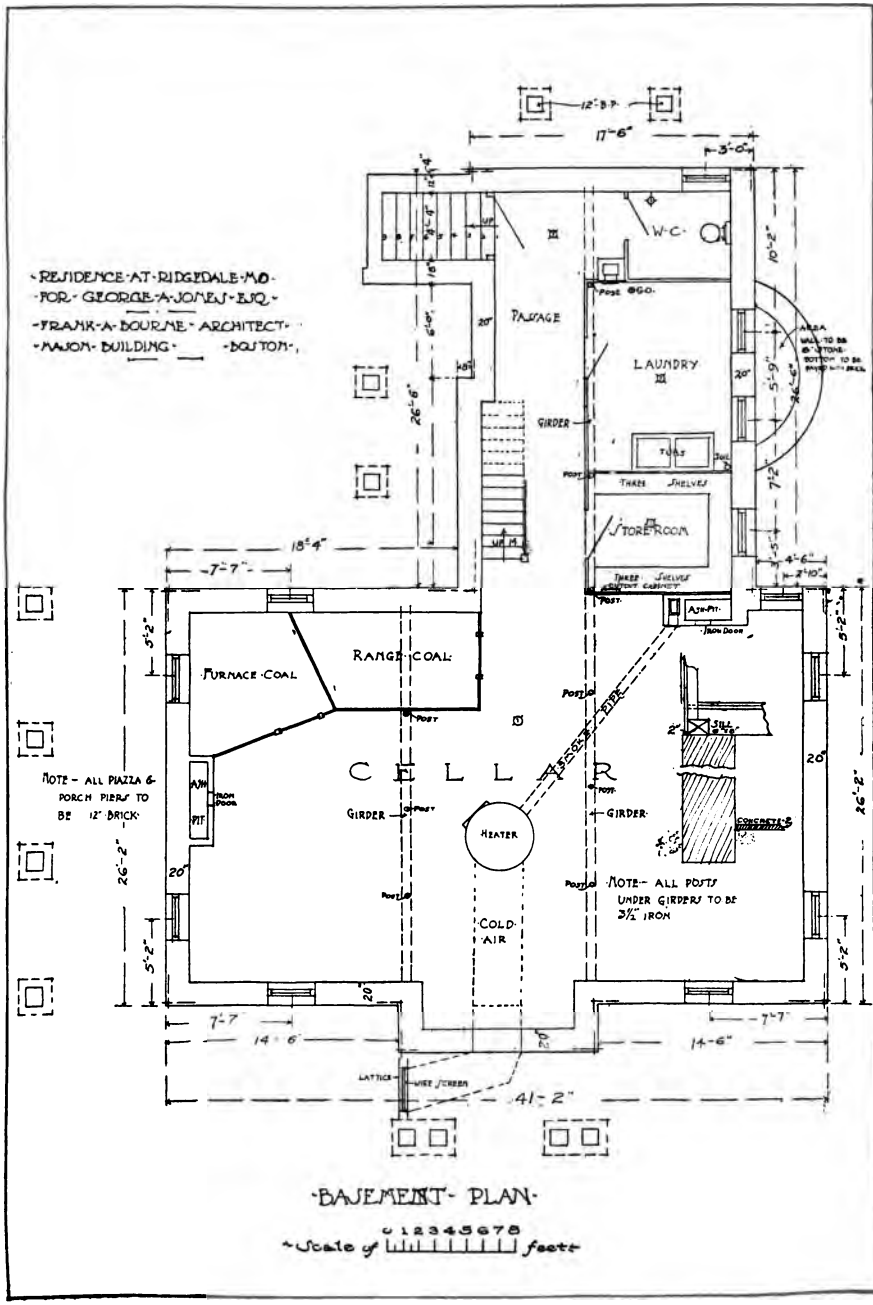


Fig. 28. Basement Plan of the George A. Jones Residence

Basement Plan. Fig. 28 shows the basement plan of the residence. Dimensions are all given to the outside of the underpinning rubble wall, which in this case is 2 inches outside the sill line, as shown in the half-inch scale section. The footings of piazza piers at the front of the house are shown dotted. On the left side of the piazza is lattice-work covering the opening into the cold-air box for the furnace. The underpinning is of stone 20 inches thick; and the piazza piers are 12 inches square, built of bricks. The posts holding the girders are usually made of iron, three-quarter-inch metal, three and one-half inches in diameter. Sometimes these posts are made of iron about one-quarter inch thick, filled with concrete, the cost being about the same as that of brick piers, with the advantage of taking up less space than the latter in the cellar. The footings of the chimneys are not shown; the ash-pit under the chimney has an iron door for cleaning; and the coal-bins are made with slides, and located conveniently near the furnace and not too far from the kitchen stairs, with the partition so placed that coal can be thrown from the window into either bin. A storeroom is built with shelves, convenient to the cellar stairs. A laundry, with set tubs, is placed in the best lighted part of the cellar. A very desirable item frequently overlooked in planning, is to allow a space at the right-hand end of the laundry tubs for the clothes-basket. The laundry should also have a chimney near the laundry stove. There are also a basement toilet-room and an outside hatchway or rollway. The windows, as a rule, should be located under the windows in the upper story; and as the basement plan is frequently used on the work separately from the other plans, all dimensions should be given, so that no reference to the other plans will be necessary. The window openings may be figured to centers, but they are sometimes figured to the brick or stone opening. The heater, or hot-air furnace, is placed near the center of the cellar. The cold-air box should be arranged so as to take air from the side least affected by the changing winds (south or east). In the case here illustrated, it has been located under the front porch.

First-Floor Plan. This, the most important of all the working drawings (Fig. 29), shows at a glance the main proportions and dimensions of the whole building, besides being the plan of what, in our American manner of living, is the principal story of the house.

This house would be located to the best advantage on a lot facing

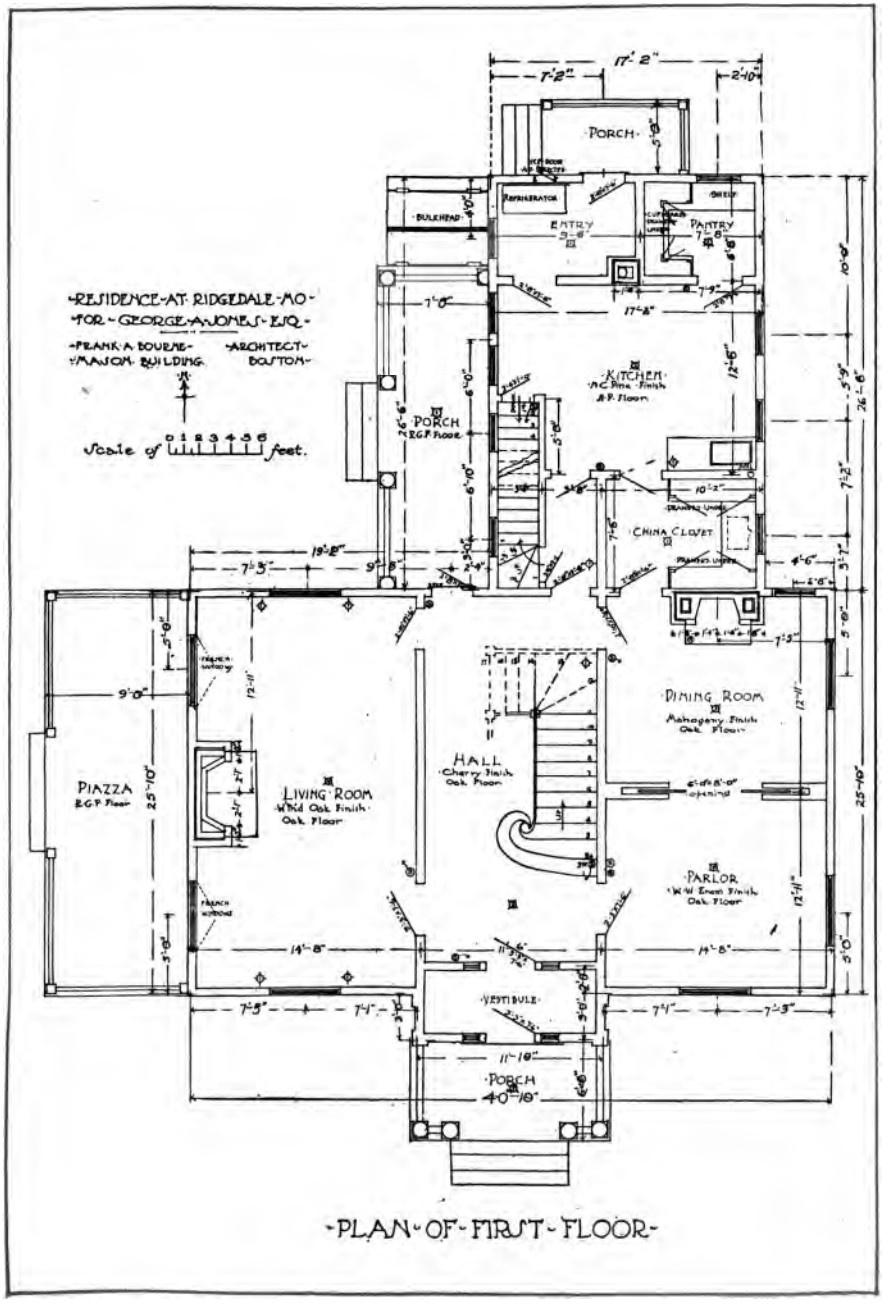


Fig. 29. First Floor Plan of the George A. Jones Residence

the south or southeast. This would put the kitchen on the north, the dining room on the east (which would give it the desirable mornng sun), and the parlor on the south and west.

The front porch sheltering the front doorway, and the vestibule and second door, form a protection necessary in cold northern climates. The hall and staircase in the center of the house open into the principal rooms. The living room on the left, 14 by 25 feet, opens by French windows on the piazza. The parlor to the right connects by sliding doors with the dining room. The living room and dining room both have open fireplaces.

From the rear of the hall a door opens on the rear porch, and another door leads to the passage connecting with the kitchen and the back stairs. Between the dining room and the kitchen is a large china closet, having glazed shelving and also a counter shelf on which is dotted the location for a china-closet sink—which, shown in this way, would not be considered a part of a contract, but could be put in later. From the kitchen a staircase leads down to the basement. The kitchen has windows on both sides, giving a cross-draft for ventilation, which is very agreeable in summer.

In the rear of the kitchen is a pantry, with cupboards, drawers, and shelving. The large back entry is planned for a refrigerator, which has an ice door on the rear, to be put in according to the directions furnished by the refrigerator maker.

This plan should be laid out like all the others, from a center axis, the dimensions being figured to outside of studs for outside walls, and to the center of partitions for inside walls, and to the centers of the window openings.

The sill line is $\frac{7}{8}$ inch inside the outside line of the walls shown, while the inner line representing the plaster surface is $4\frac{3}{4}$ or $4\frac{7}{8}$ inches inside the sill line. The dimensions being given in this way, it is a simple matter for the carpenter on the building to run his measuring stick between the outside studding and against the outside boarding, and to measure across, thus locating the center of an interior partition or the center of one of the windows. The location of gas and electric fixtures is shown by circles on the plans.

Second-Floor Plan. This is shown in Fig. 30. Only those dimensions are given on these plans which are not indicated on the first floor, as all second-floor partitions are supposed to rest on the

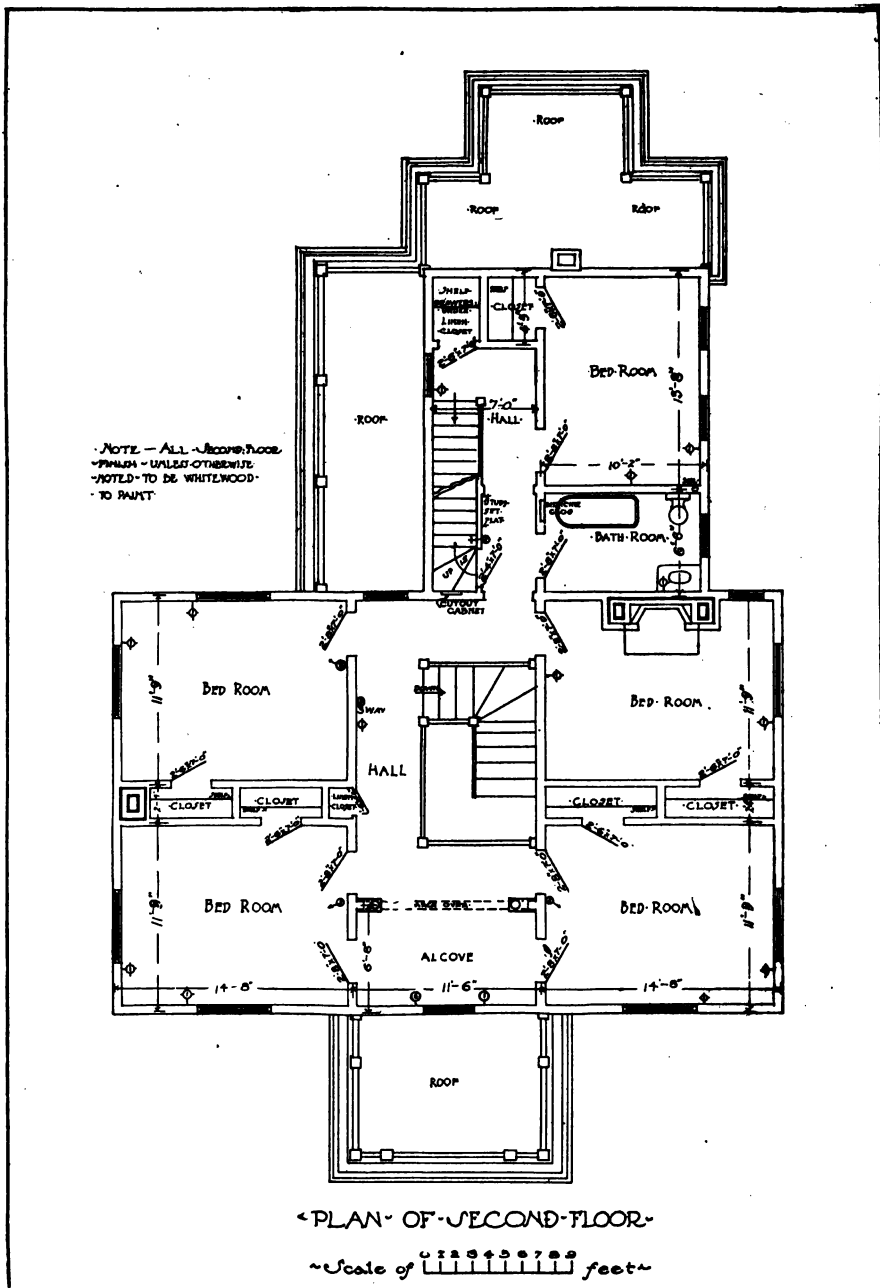


Fig. 30. Second Floor Plan of the George A. Jones Residence

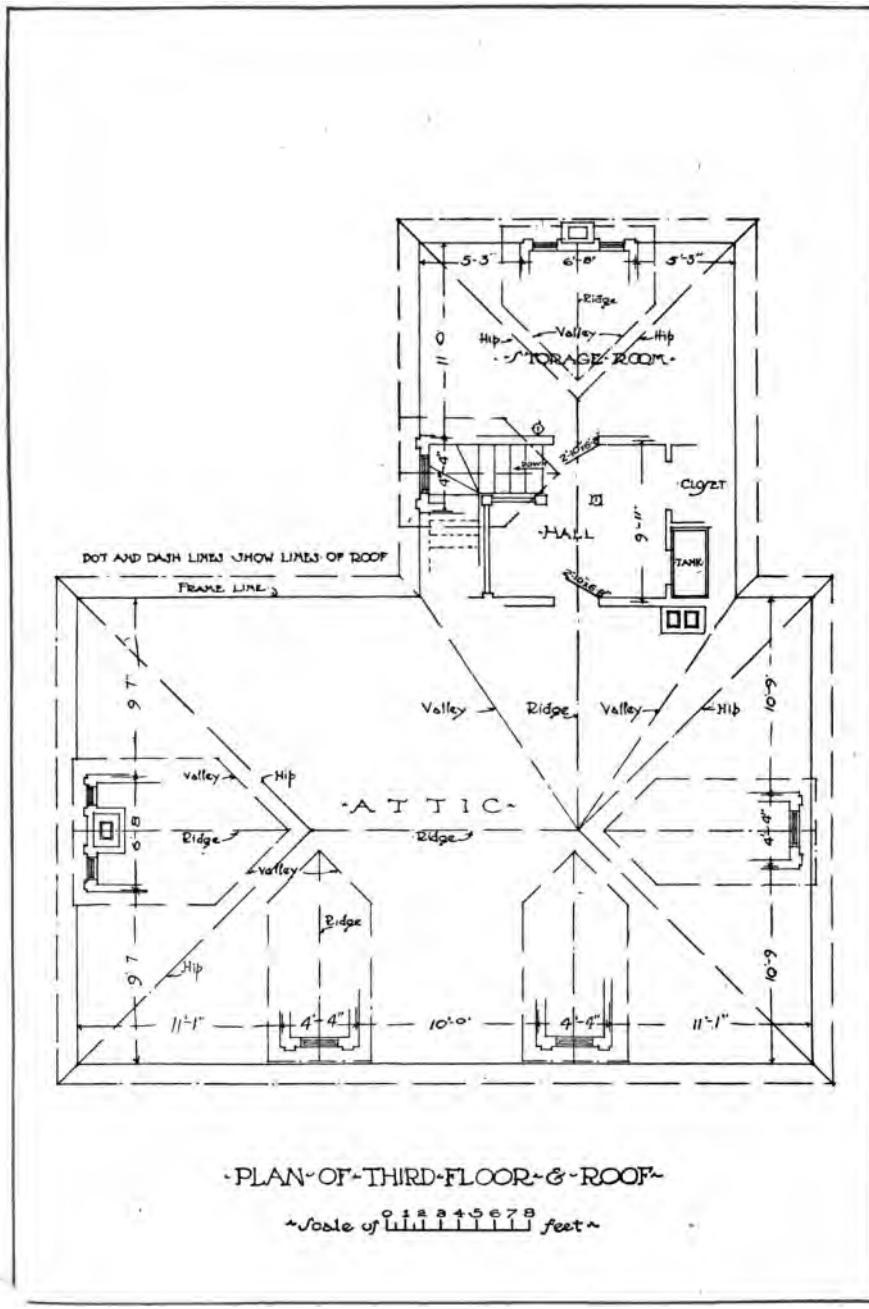


Fig. 31. Third Floor and Roof Plan of the George A. Jones Residence

partitions below, if possible. The roofs of the porch and piazza are shown. These may be covered with painted canvas or with tin, and, if they are to be much used, should be provided also with a floor of wood slats. The staircase and hall are shown with an alcove opening toward the front, lighted from the window over the front porch. This alcove is separated from the hall by an arch resting on small columns, making an attractive sitting room. There are doors from it into the adjacent bedrooms. Instead of the arched opening, a partition may be put in, making a convenient dressing room. The bedrooms are 11 by 14 feet, and are provided with closets.

One bedroom has a fireplace, and the two bedrooms on the left of the house have access to a chimney. There is a small linen closet, provided with wide shelves, opening out of the hall. Sometimes the lower part of this closet is provided with drawers, and the upper part with wide lockers having drop fronts. The opening between the front hall and the rear hall can be closed with a door, if desired; or the door can be placed opposite the partition between the bathroom and the rear bedroom. The bathroom comes directly over the butler's pantry, so that the plumbing is all very compactly arranged. The staircase to the attic goes up over the back stairs that lead down to the kitchen. The rear bedroom, which could be used as a servants' room, is provided with a large closet. A large linen closet, with shelves and drawers, opens into the rear hall.

Attic and Roof Plan. The attic, as shown in Fig. 31, is left unfinished, with the exception of the hall at the top of the back stairs. The location of the tank is shown near a chimney, and a small closet opens off the hall. The roof lines are shown by dot-and-dash lines, which are frequently drawn in red on the working drawings. The frame line (*i. e.*, the line of the outside of the sill and the studding)—which should appear on all the working drawings—is shown here in full, with all dimensions noted thereon.

Front and Side Elevations. As shown in Figs. 32 and 33, the character of the house is "Colonial," of about the period of the beginning of the nineteenth century. The treatment is very simple and the details should be worked out delicately to obtain the Colonial character. The construction is comparatively simple, the base being of brick, sometimes with a granite course at grade, and sometimes the whole underpinning being of split granite. The wall is covered with

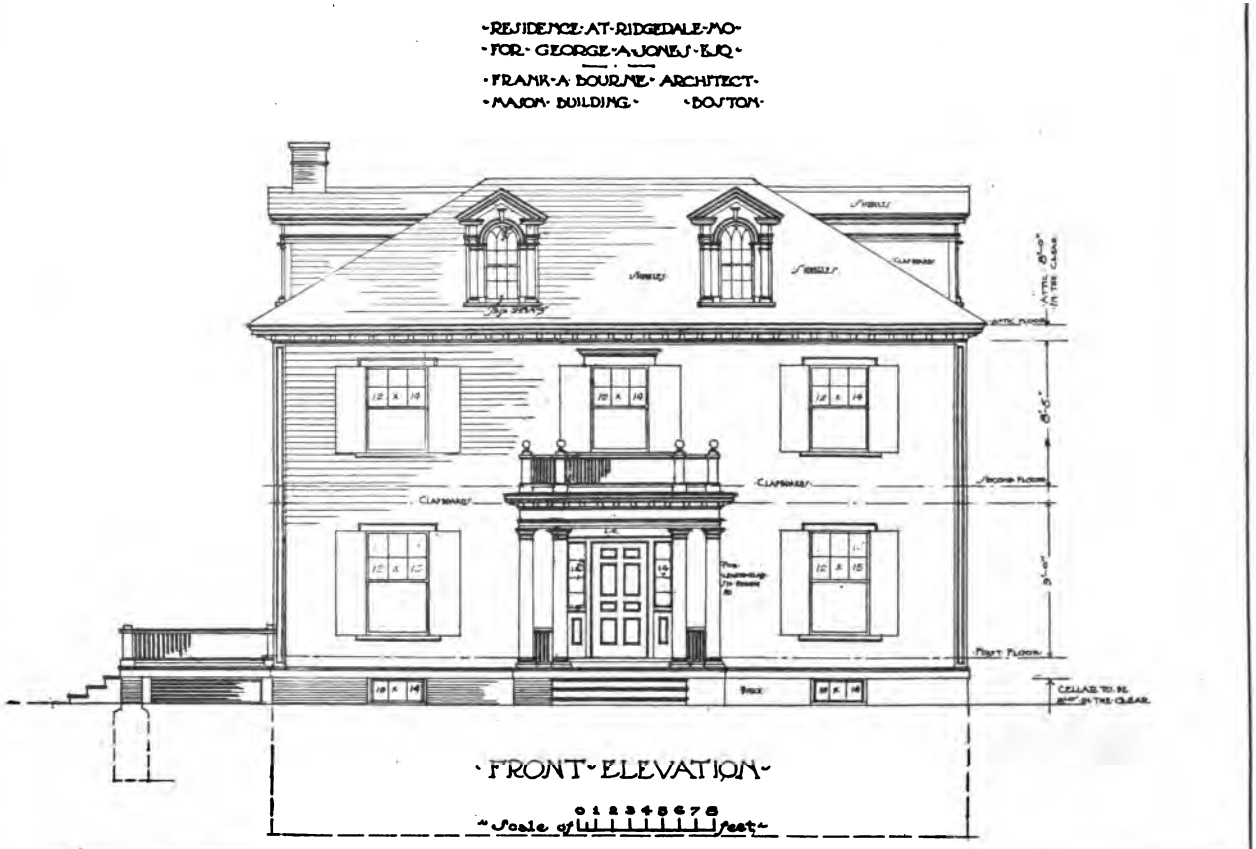


Fig. 32. Front Elevation of Residence for George A. Jones at Ridgedale, Missouri

Fig. 33. Left Side Elevation of Residence for George A. Jones at Ridgedale, Missouri

Fig. 34. Detail of Front Elevation of the George A. Jones Residence

clapboards, with cypress or pine finish. The roof is covered with shingles. The location of the floors is shown by a dot-and-dash line, which in working drawings is frequently put in in red ink. The height of the floors is 9 feet for the first story, 8 feet 6 inches for the second story, with an attic 8 feet in the clear. The cellar is to be 8 feet high in the clear.

Detail of Front Elevation. Fig. 34, showing detail of the front elevation, is reduced from a drawing made at a scale of one-half inch to the foot. This is sufficiently large to show very clearly to the workmen the relation and character of the mouldings, which must, of course, be worked out at full size. The cornice and the front entrance are here shown, the cornice consisting of the Roman Doric Order, as treated in the Colonial period, the column having a modified Attic base, and a shaft with the customary entasis. This entasis or swelling of the column extends one-third of its height without diminution, and tapers slightly until it comes to the necking. The cap is very simple, consisting of astragal, necking, fillet, and echinus, all turned; a square abacus, consisting of a fascia, ogee, and fillet. The architrave consists of a fascia, small bead, another fascia, ogee, and fillet. The frieze in this type of building is usually plain; and the cornice, which may be greatly varied, consists, in this case, of a great quarter-hollow, fillet, quarter-round, fascia with brackets, and a corona consisting of fascia, fillet, and cyma. Between the columns is a balustrade with turned balusters. The cornice is surmounted by another balustrade with posts, top and bottom rail, and turned balusters. The doorway is worked out in old Colonial style, with paneling peculiar to that period. The sash may be made either according to the design shown, in wood, or with wide leads, which may be painted white. Windows are shown with outside casing and back band; and the center window has a small cap to accent the central portion of the house. The water-table is formed to take up the slight projections of the brick underpinning beyond the outside boarding. It consists of a wide fascia, an astragal, and a splayed member. The corner is paneled, as shown. Sometimes a plain corner-board is employed, and at other times it is made larger and finished with a Classic capital and base. The cornice of the house is similar to the cornice of the porch, the frieze and architrave being omitted, as is quite customary on Colonial houses, although there are examples of Colonial houses where the complete en-

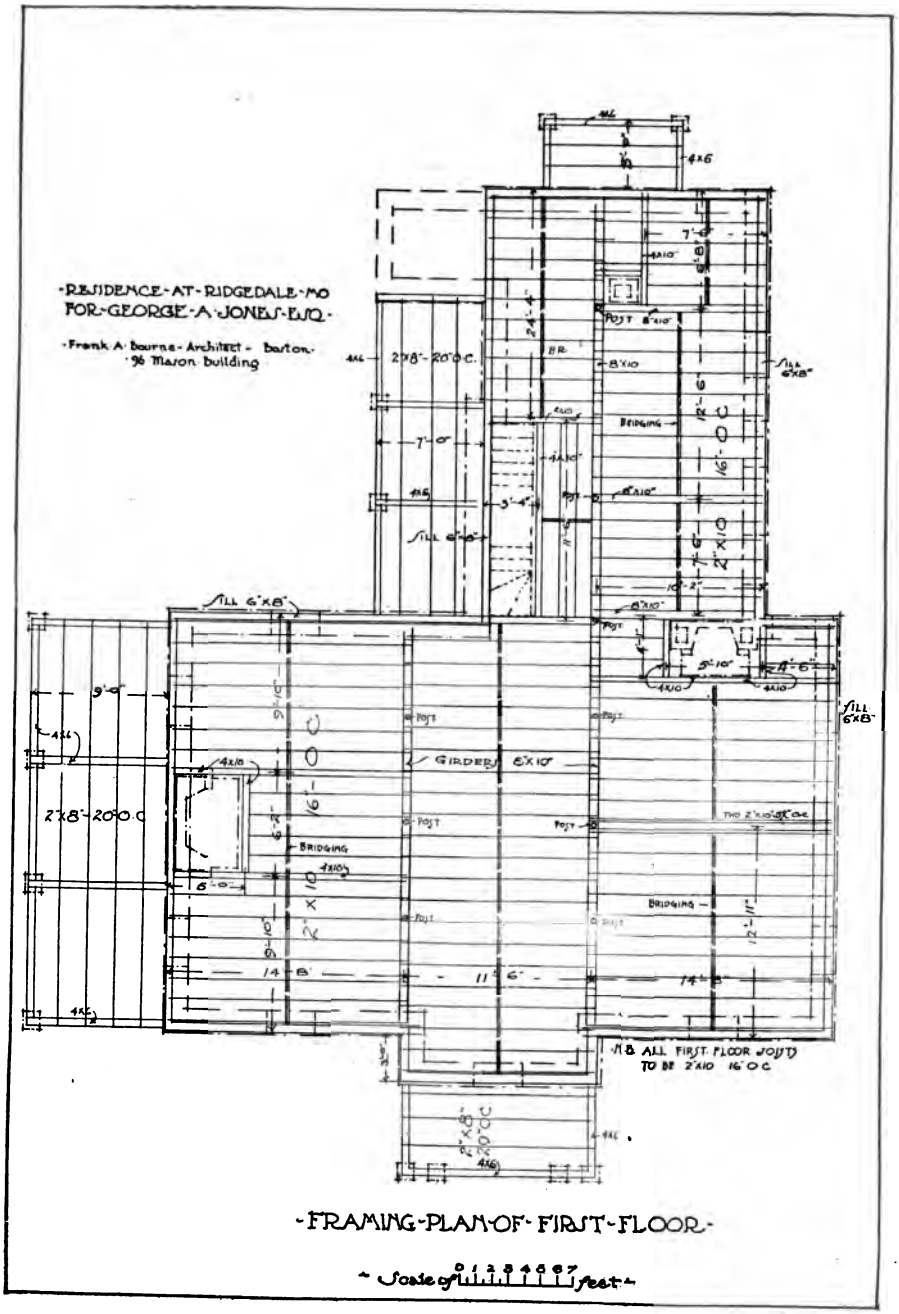


Fig. 35. Framing Plan of First Floor of the George A. Jones Residence

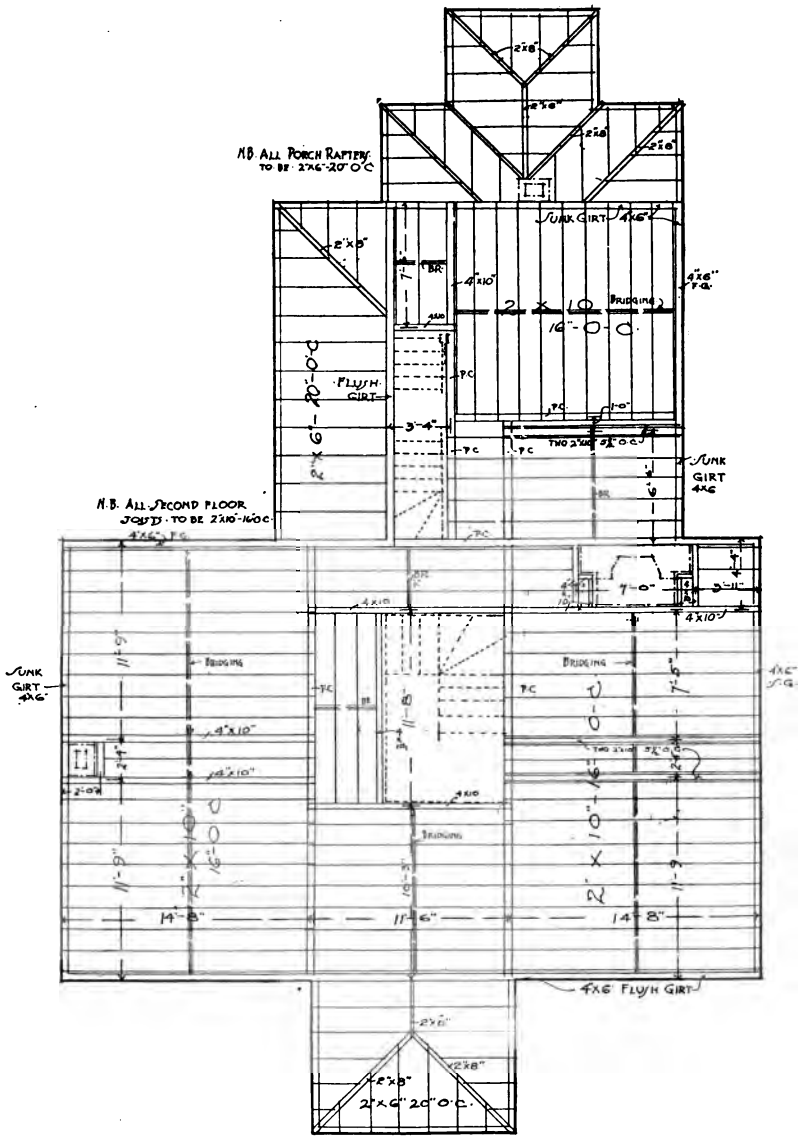
tablature is used. The dormer shows a peculiar Colonial treatment, using a small Doric Order on each side of the arched window. The muntins of the sash are generally worked out in wood. At the side of the roof is shown a side elevation of the dormer.

First-Floor Framing Plan. (Fig. 35.) The supports shown with a dot-and-dash line would usually be shown in red ink in the working drawings. The sill, 6 by 8 inches, laid flat, is shown with a full line running all around the building. The girders and the posts on which they rest are shown in a full line, the girders being 8 inches by 10 inches, and the posts not over 10 feet apart. The piazza girders are 4 by 6, and the piazza sills are 4 by 6. The piazza floor joists are 2 by 8 inches, 20 inches on center. The dimensions are given to the outside of the sill, and to the centers of the partitions. Where the partitions come over each other and are parallel to the joists, a joist is set 1 inch each side of the studs of the partition, so that the rough floor boards may run directly through and leave room for nailing for the finished floor each side of the partitions. Trimmers and headers are double the size of their respective floor joists, being 4 by 10 inches in this case. All joists are set 2 inches clear of the fireplace openings. The distances are given to the centers of the trimmers, but sometimes dimensions are given for the clear opening. All the first-floor joists are to be 2 by 10, placed 16 inches on centers. The bridging is shown dotted. This is made of 1 by 2½-inch stock set diagonally between the joists.

It will be noticed that all the 2-inch joists except those in special locations—for example, under a partition, as above mentioned—are shown with only a single line, all other timbers being shown with a double line.

Second-Floor Framing Plan. The second-floor framing plan (Fig. 36) is similar to the first-floor, the girts, 4 by 6 inches, being shown instead of the sill. The framing of the roofs of the porches is shown, and notes are made where the girts are flush or where they are sunk. In certain cases it will be noticed that the joists are carried through, continuous. It often happens that shorter stock might have been used at no disadvantage to the building. The joists across the building should be nailed together wherever possible, so as to make a complete tie across the building.

Attic Framing Plan. On this drawing (Fig. 37), the roof plate is shown, and also the location of the hard pine ledger-board. The



FRAMING PLAN OF SECOND FLOOR

Scale of 0 1 2 3 4 5 6 feet

Fig. 36. Framing Plan of Second Floor of the George A. Jones Residence

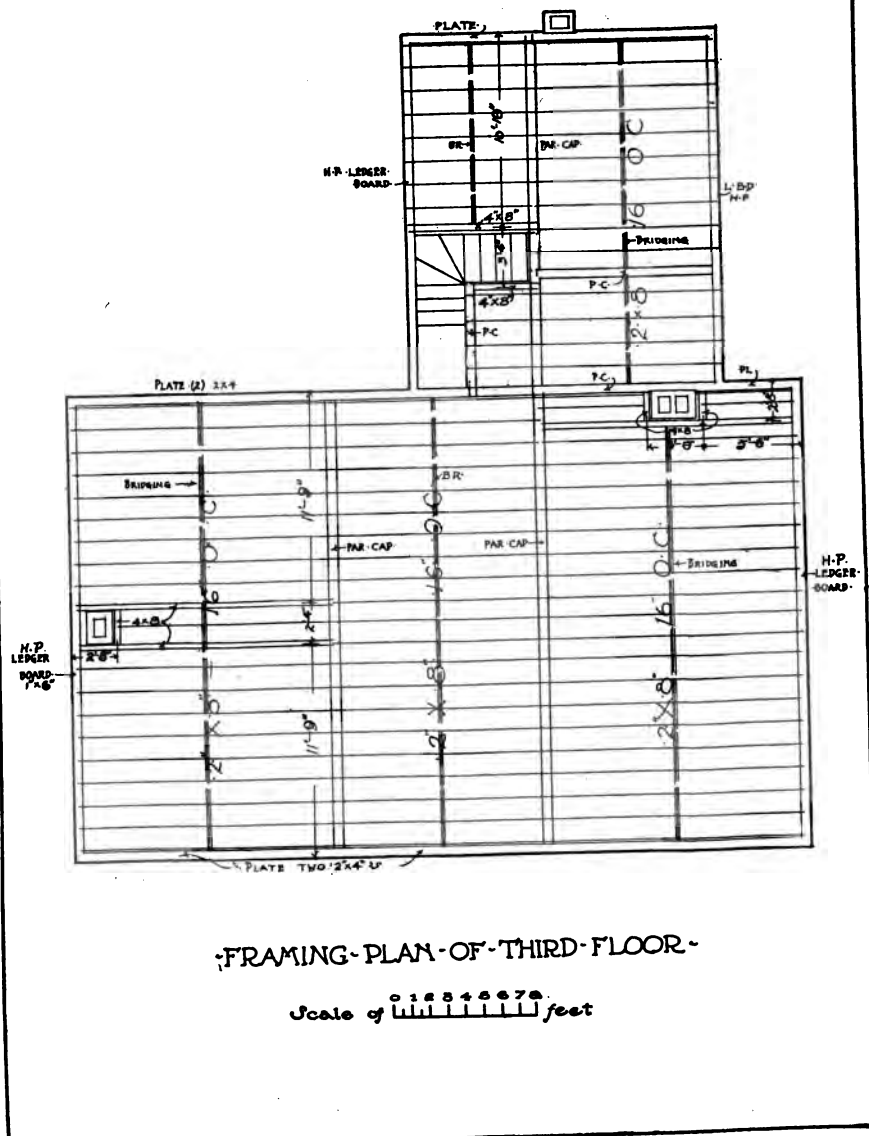


Fig. 37. Framing Plan of the Third Floor of the George A. Jones Residence

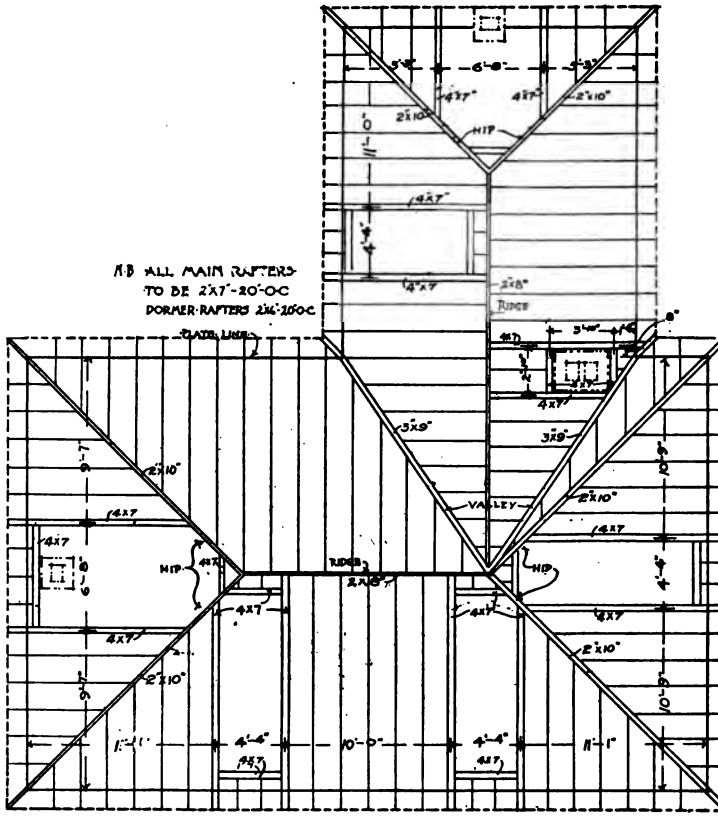


Fig. 38. Framing Plan of Roof of the George A. Jones Residence

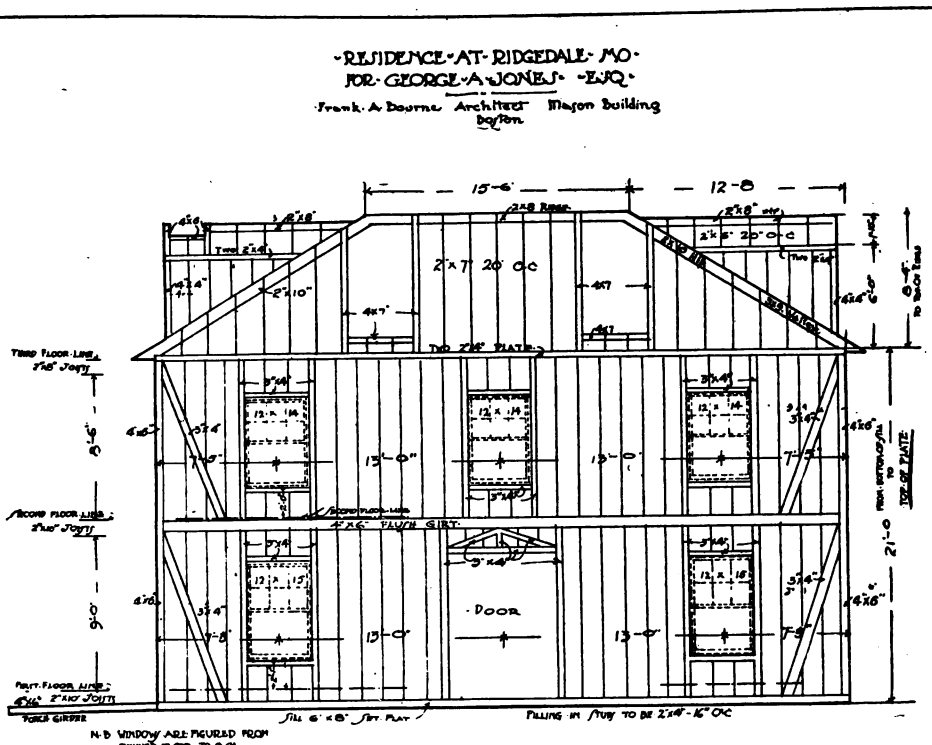


Fig. 39. Framing of Front Elevation of the George A. Jones Residence

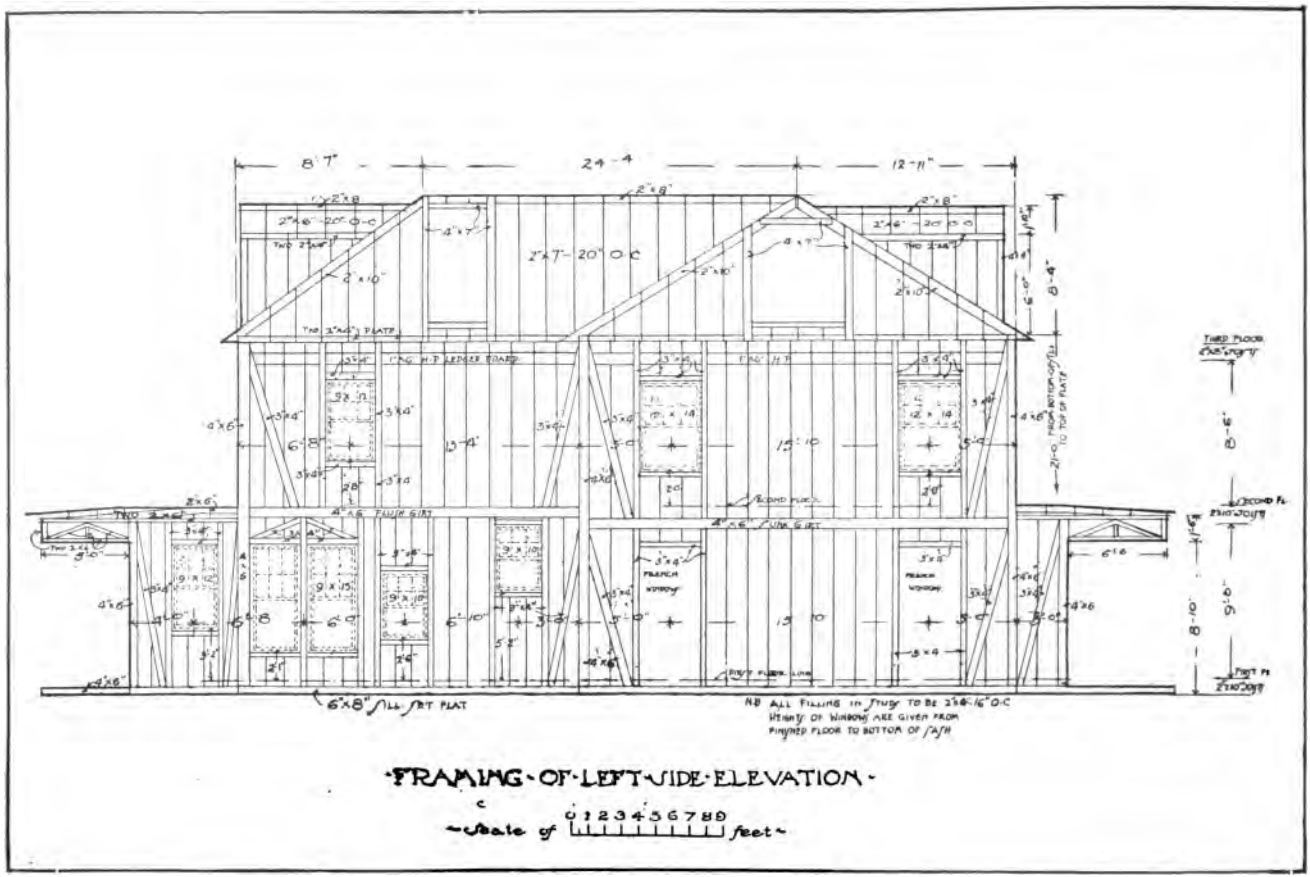


Fig. 40. Framing of Left Side Elevation of the George A. Jones Residence

partition caps of the story below, on which the joists rest, are shown. The joists in the attic floor are 2 by 8, placed 16 inches on centers.

Roof Framing Plan. The rafters and hips are shown (Fig. 38) 2 by 10; the valley rafters, 3 by 9; the ridge, 2 by 8 inches. The rafters either side of the dormer openings are 4 by 7, and the headers for the dormers are also 4 by 7 inches. All the other main rafters are 2 by 7 inches, placed 20 inches on centers; and the dormer rafters, 2 by 6, placed 20 inches on centers. The plate line, which is the same as the first-floor sill line, is shown as a full line, and the dimensions are given from this line.

Framing of Front Elevation. The framing of the front elevation of the house above the foundation is shown in Fig. 39. The sill is 6 by 8, resting on its 8-inch face. The corner posts are 4 by 6, framed into the sill; and a 4 by 6 flush girt is shown running around the house. It will be noticed that the girt stops on the side elevations where it is marked "4 by 6 sunk girt" (Fig. 40). The plate is formed of 2 by 4 joists, which break joints all around the building. The frame is braced by 3 by 4 studs, these braces being as long as possible, which is considered better construction than the former short-brace system. In cheaper work, 2 by 4 braces, halved into the studding, are sometimes used in the same position. The filling-in studs are 2 by 4, set 16 inches on centers. The door and window studs are 3 by 4 inches, set 5 inches clear of the sash opening.

The dimensions are given to the centers of the openings. The heights are generally given to the finished floor, which would be 2 inches above the joist line. The large openings are trussed, as shown over the front door opening. The rafters are 2 by 7, set 20 inches on centers, the hips being 2 by 10, and the valley rafters 3 by 4. The dormers are built up of 4 by 4 corner posts and 4 by 7 rafters each side of the opening. The ridge is 2 by 8, the distance to the top of ridge being given above the top of the plate, and all the points on the ridge rafters and ridge may be located on the sill line to the junction of the hip.

Framing of Side Elevation. The sill, girts, corner posts, studding, plate, and rafters (Fig. 40), are similar to those already described on the front elevation. The framing of the front and rear porches is also shown, with the dimensions given similarly. The attic floor joists

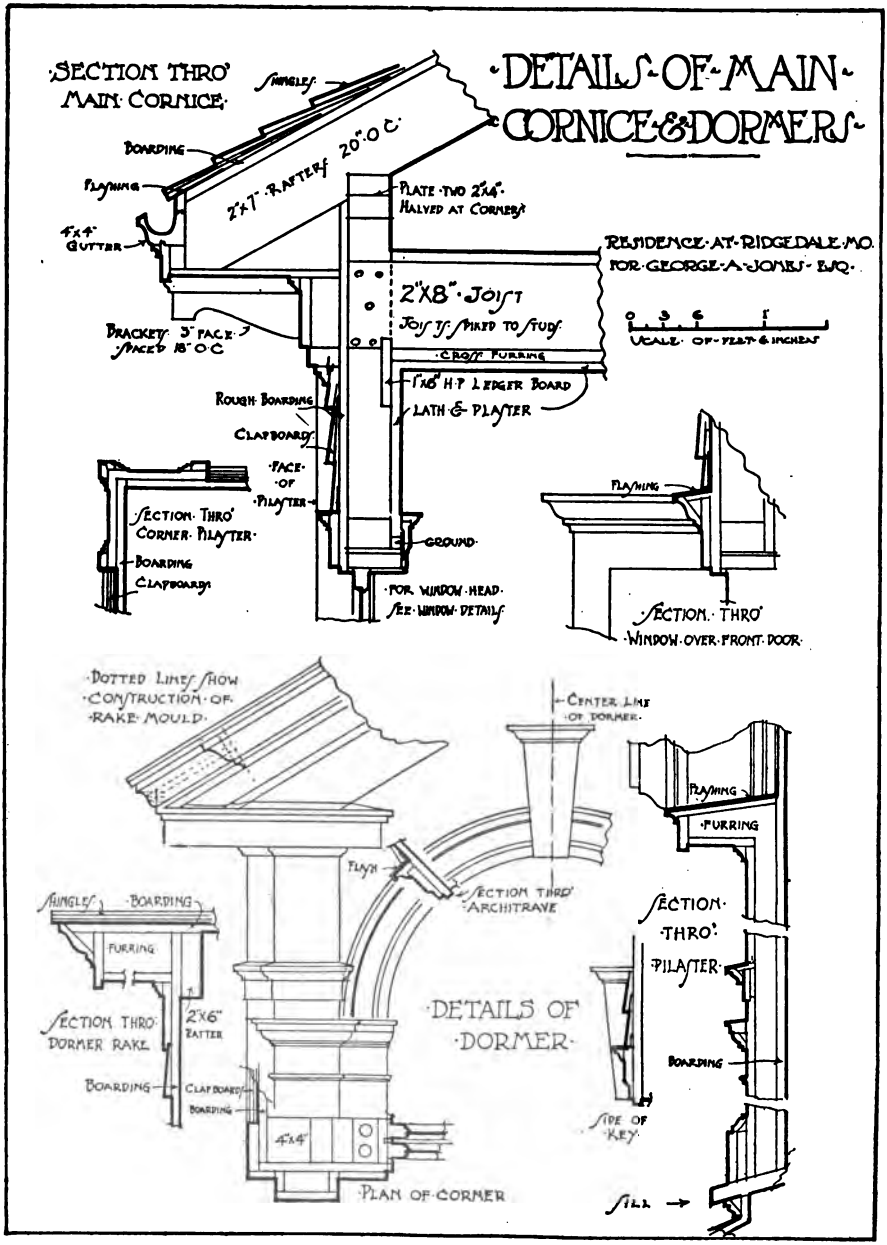


Fig. 41. Details of Main Cornice and Dormers of the George A. Jones Residence

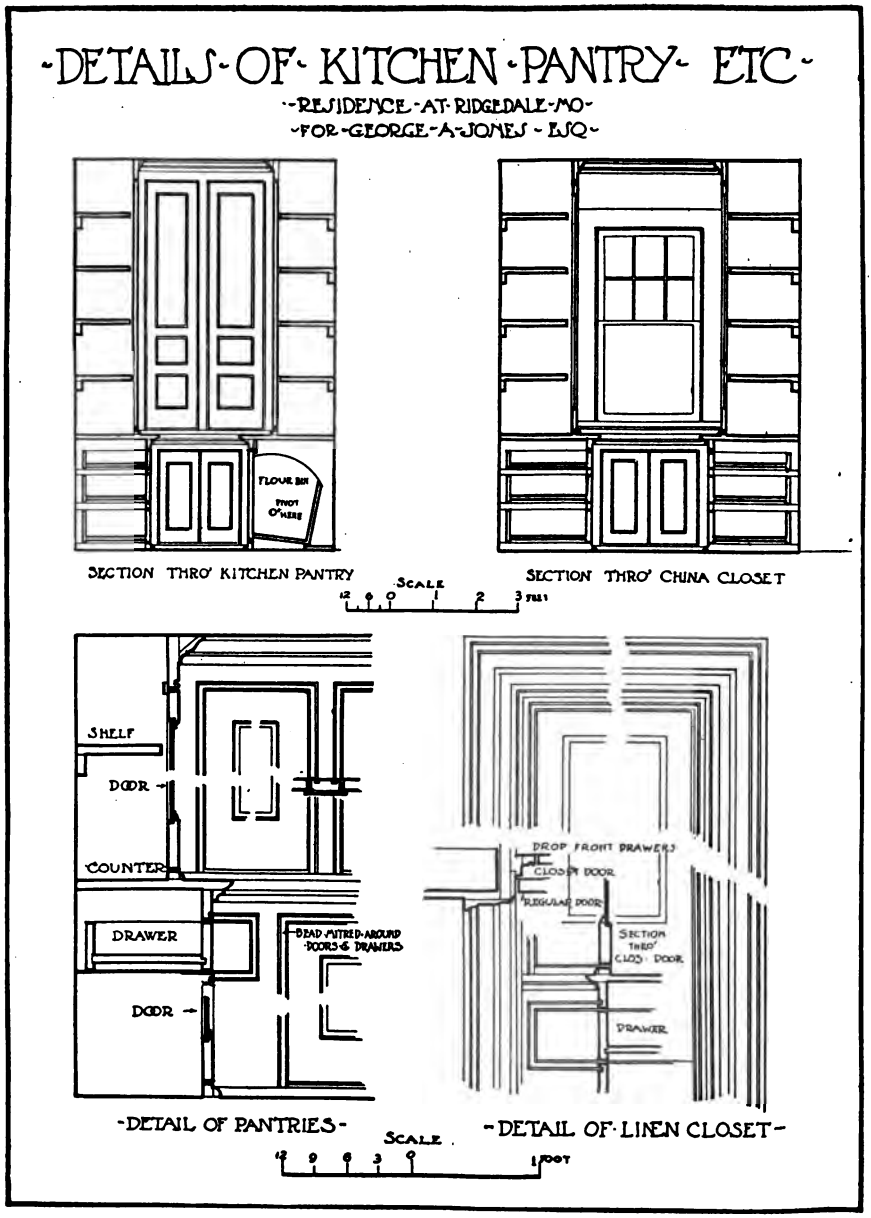


Fig. 42. Details of Kitchen, Pantry, etc., of the George A. Jones Residence

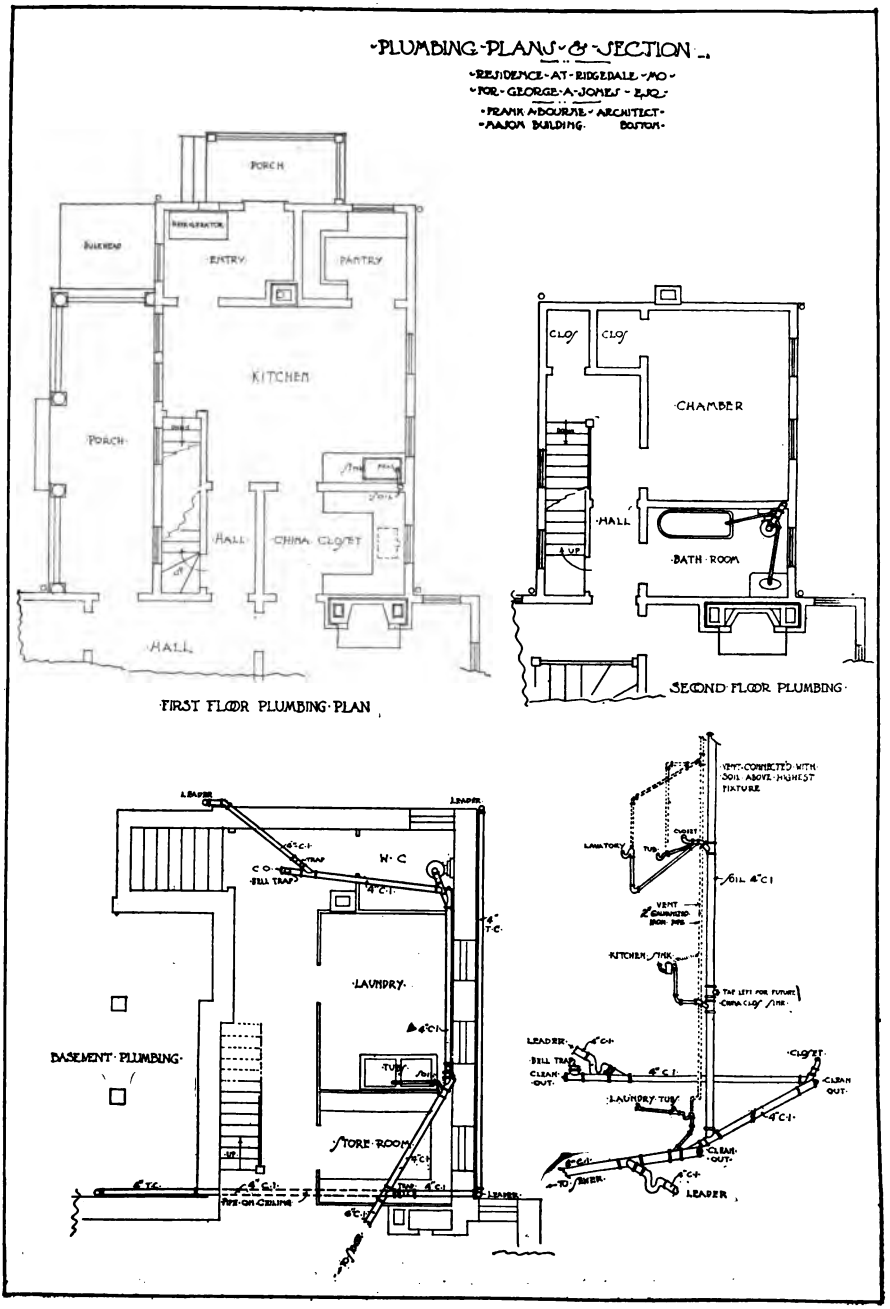


Fig. 43. Plumbing Plans and Section of the George A. Jones Residence

are supported on a 1 by 6 hard pine ledger-board, which is cut into the studding after the manner of balloon framing.

Main Cornice and Dormer. Fig. 41 is reduced from a drawing made at a scale of three-fourths inch to the foot. This plate should be drawn out at the original scale mentioned; and a full-size pencil study should be made for comparison.

Kitchen, Pantry, and China Closet. Fig. 42 shows the details of kitchen, pantry, and china closet reduced from a drawing made at a scale of one-half inch to the foot, and larger details at a scale of one and one-half inches to the foot, showing shelving, lockers, and doors. These are all included in the interior finish, and should follow the specifications as to sizes. The mouldings should all be full-size.

Plumbing. Fig. 43 shows the plumbing details for this building. These details are carried somewhat further than is usually done on plans, but no further than advisable, as they will be found of great assistance in carrying out and superintending the work. The basement plan shows the direction of the sewer connection, which is a horizontal pipe, six inches in diameter, of cast iron, located either on the basement ceiling or in a trench on the cellar floor. In this case it must be below the cellar-floor level in order to take the laundry tubs. The section shows the elevations of the pipe carried up through the house.

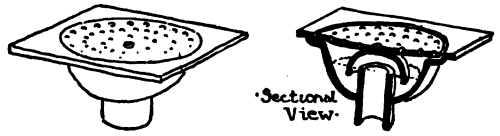


Fig. 44.

There will be a trap between the point shown and the sewer, just outside the wall of the house. The leader connections are 4-inch cast-iron pipe inside the house in cellar floor, and 4-inch terra-cotta outside the house, to take the water from the gutters and conductors. On the first connection there is a cleanout, and the size of the pipe is reduced from 6 inches to 4 inches. There should be cleanouts at every bend, and also at about every fifteen feet of horizontal run. There should be a bell trap (Fig. 44) to take the cellar surface water, also branches for general fixtures through the house, as shown. The vertical pipe of 4-inch cast iron would rest on a brick pier at the bottom built by the mason.

The vent pipes from the trap of every fixture are shown in dotted lines, and are carried up beyond the highest fixture, where they may be

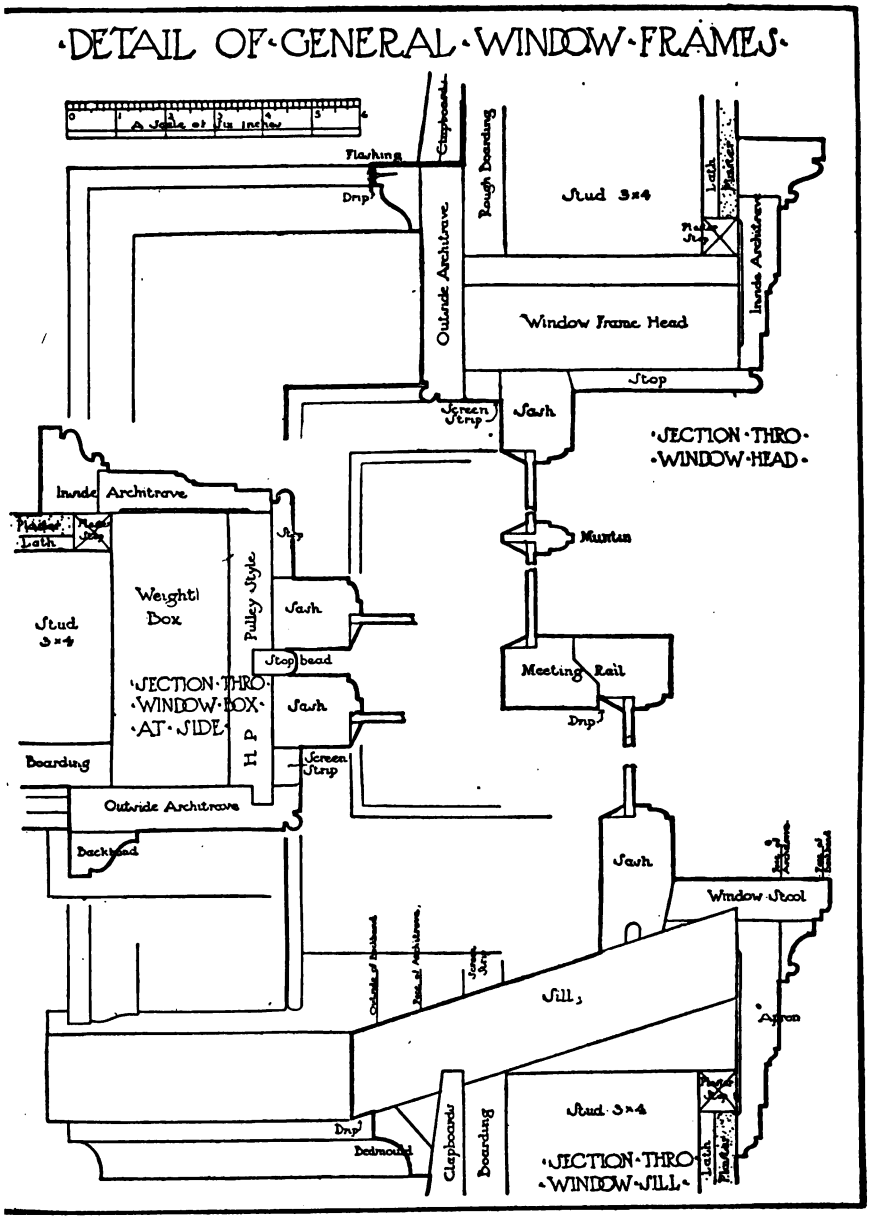


Fig. 45. Detail of General Window Frames for the George A. Jones Residence

carried back into the soil pipe or through the roof. Branches are taken off for the laundry tubs, china closet, sink, lavatory, tub, and closet, as shown in the section and on the first and second-floor plumbing plans. Sometimes these pipes are shown in blue on the regular working drawings; but there is an advantage in having them on a separate sheet, as has been done in this detail. The vent pipes from the traps may be of 2-inch cast iron or of 2-inch galvanized wrought iron. This practice varies with the building laws in different localities.

Detail of General Window Frames. Fig. 45 shows the method of laying out a full-size detail of a window box. Such a drawing is one of the first things usually given to a draftsman on entering an architect's office, and one of the most important details of house building to become acquainted with. The drawing shows an elevation of the lower left-hand corner and upper left-hand corner of the window-frames seen from the outside. The lower part of the drawing shows a section through the window sill. Taking the scale of 6 inches shown at the top of the drawing, it would be found that the window sill can be made from 2-inch stock finished about one and three-quarters inches thick. On the outside, next to the clapboards, is a bed-moulding, and the slope of the sill forms a good drip to throw off water. The clapboards are housed into the under side of the sill. The sill rests on a 3 by 4 or 4 by 4 horizontal stud under the window opening. The inner side of the sill is cut to come on a line with the finished plaster. The plaster stop or ground, which is either three-quarters or seven-eighths inch thick, according to the proposed thickness of the plaster, is nailed on to the 3 by 4 stud. The space between the stud and the sill is frequently filled with mortar. At the left of the drawing is shown a section through the side of the window box.

The outside architrave is arranged on the outside of the boarding; and a back band, or moulded strip, forms a finish around the outside edge. The layers of paper are generally run on the boarding under this outside architrave; and sometimes zinc flashing is used in very exposed positions, being turned up against the outside architrave. The small three-quarter round bead shown in the drawing may be omitted. The 3 by 4 stud is set so as to leave space for the weights. It is a good rule to remember that the distance from the stud to the glass opening is 5 inches, and the distance from the sill stud the same. The distance from stud at window head to glass opening is 4 inches.

The pulley stile is of hard pine; and the parting strip, or stop-bead between the two sashes, is also hard pine. Between the outside architrave and the sash is put in a small screen strip, to give space enough for a mosquito screen between blinds and sash. On the inside of the sash is a stop-bead, which forms a part of the interior finish and covers the rough part of the window frame.

The upper part of the drawing shows a section through the window head. Sometimes the window frame head is made of thinner stock than that shown. This completes the rough window box as it is shipped from the sash factory to the building. At the building, it is nailed in place against the rough boarding; and later the sash, which come a little too large for their position, are fitted into place. Sections horizontally and vertically are shown through the sash, including meeting rail and muntins. The sash at the sill is wider than elsewhere, and underneath is usually beveled where it comes against the finished window stool, so that it will shut tight. There is also usually a groove underneath, to intercept any water that may blow in. The meeting-rail may be made on the outside sash, to drop below the meeting-rail on the inside sash, forming a drip which will prevent the water washing down on the glass of the lower sash.

The inside finish is frequently included on the general interior-finish drawings of the building, and is not always sent out with the window-frame details. The window stool is shown on the drawing, with a small space underneath where it comes against the sash, which forms a slight interruption for any water that may pass the other groove. The apron is nailed onto the sill and plaster stop; and a moulding is generally run under the window stool where it joins the apron. A back band may be laid around the inside architrave, against the plastering; or the inside architrave may be all one piece.

Fig. 46 shows several variations from the details of window frames illustrated in Fig. 45; and these can be still further varied if desired; or a combination of the parts may be made, taking certain details from each detail given.

The frames, unless otherwise shown, are usually made of white pine. Pulley stiles and parting beads are made of hard pine.

The pulley stiles are seven-eighths inch thick, tongued into the outside casings, as shown in the section through the side of the window box. The parting or stop beads are seven-eighths by one-half inch in

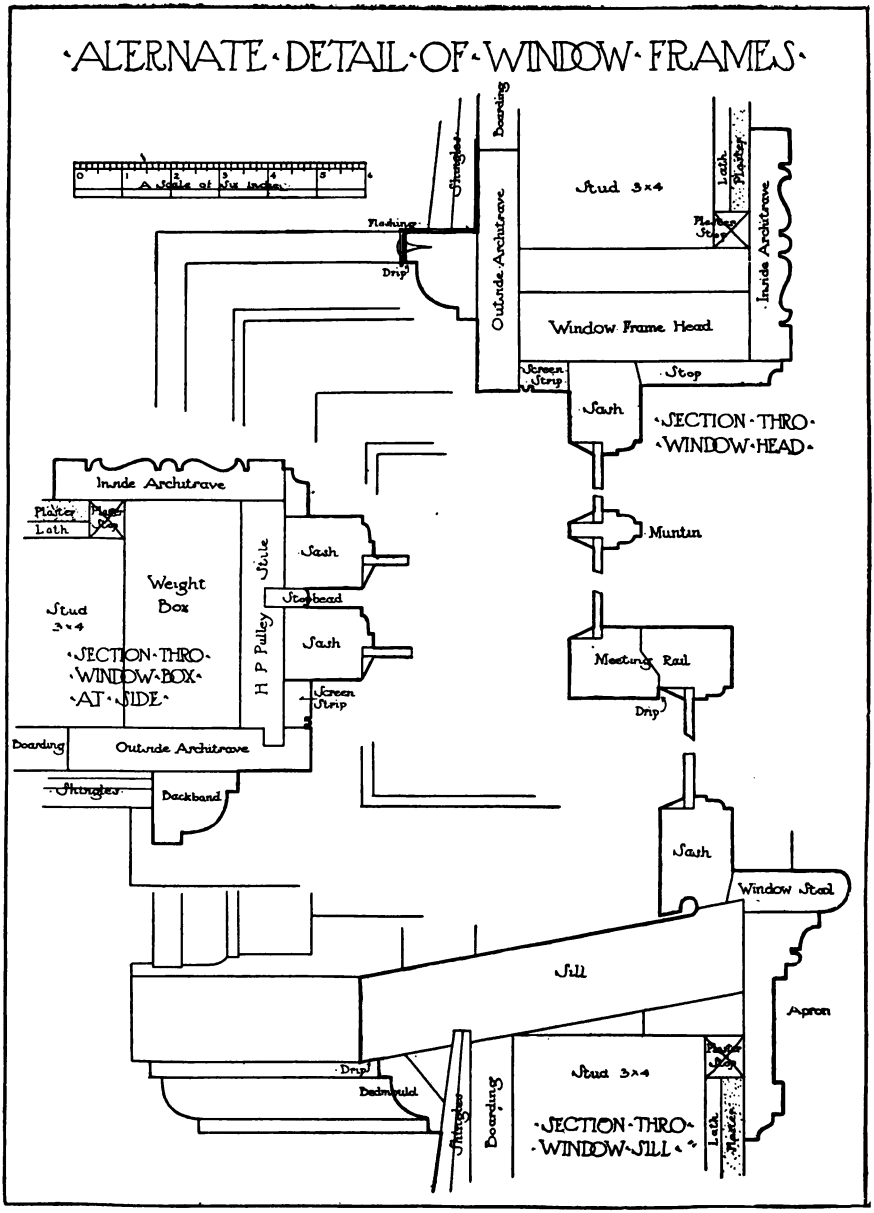


Fig. 46. Alternate Detail of Window Frames of the George A. Jones Residence

size; sometimes they are made seven-eighths by three-eighths inch, the latter giving more room for the screen strip.

When two-coat work is specified for plaster, the plaster stops are generally three-quarters inch thick; when three-coat work is used, generally seven-eighths inch thick. Very often the window box is completed by ground-casing either three-quarters or seven-eighths inch thick, as shown in Fig. 47; in this case no ground or plaster stops are necessary around the window frames. The yoke or window-frame head is generally made one and three-eighths or one and one-half inches thick. The sills are set to pitch one and one-half inches. Care must be taken to see that the blinds are made sufficiently long to fit, as stock frames are frequently made with a slope of not over one-half inch in four inches. The outside casing—or outside architrave, as it is sometimes called—may be set either flush with the boarding or outside the boarding. When it is set flush with the boarding, the shingles may be carried directly across the joint, and finished against a back band, which comes around the outside of the window frame. The outside casing is generally seven-eighths inch thick, and five inches or sometimes four and one-half inches in width. In certain cases it is made of one and one-eighth inch stock, when it is to be set outside the boarding. Sometimes, instead of the back-band shown, an architrave made from one and one-eighth to one and three-quarter inch stock is planted on the outside casing. This would show the distinction between the outside casing and the outside architrave. The method of using a ground casing and outside casing flush with the boarding is inexpensive, and therefore in quite common use. It does not give sufficient room for a screen strip, and does not make a very tight casing where the pulley stile connects with the sill.

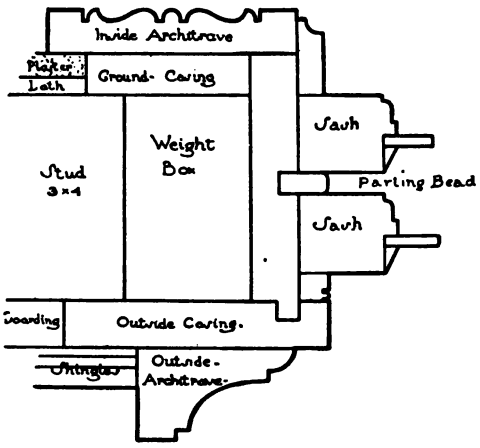


Fig. 47.

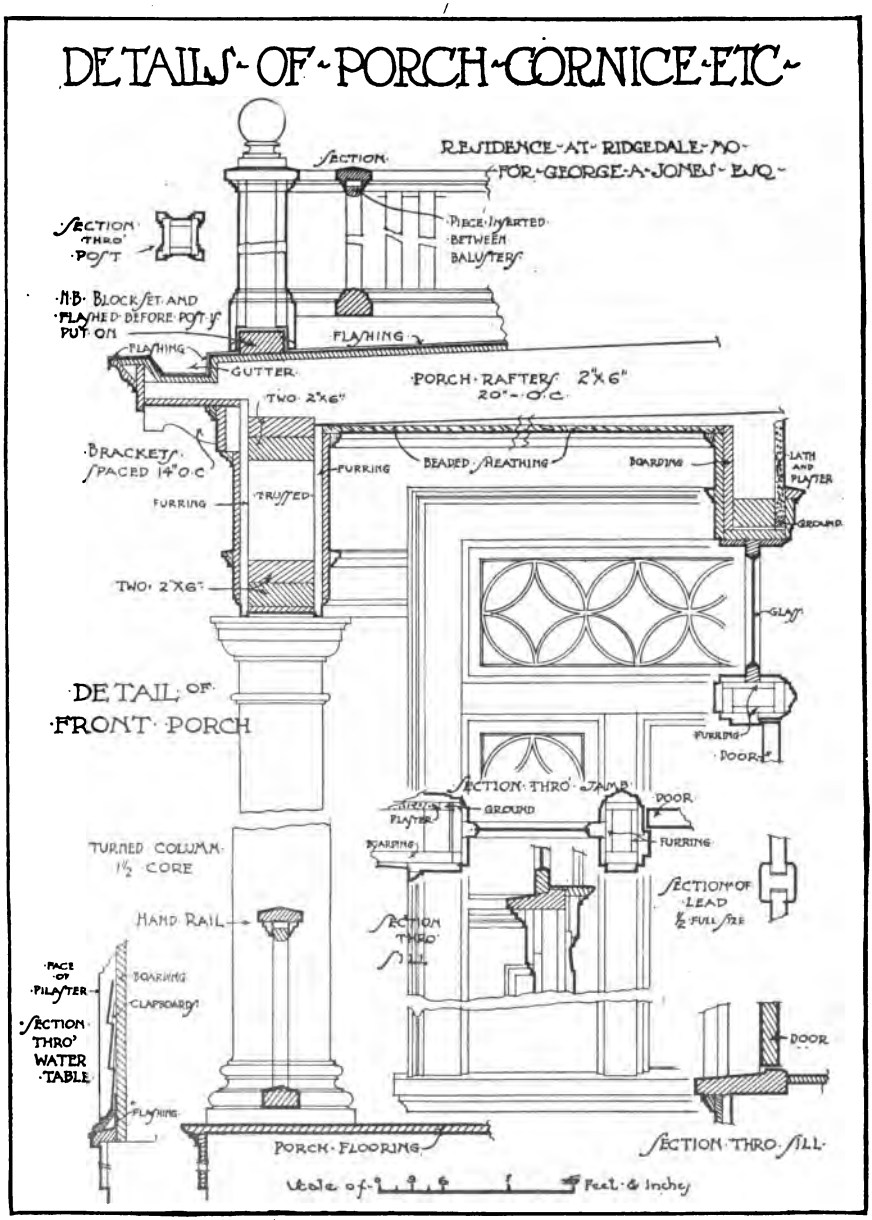


Fig. 48. Details of Porch, Cornice, etc., of the George A. Jones Residence

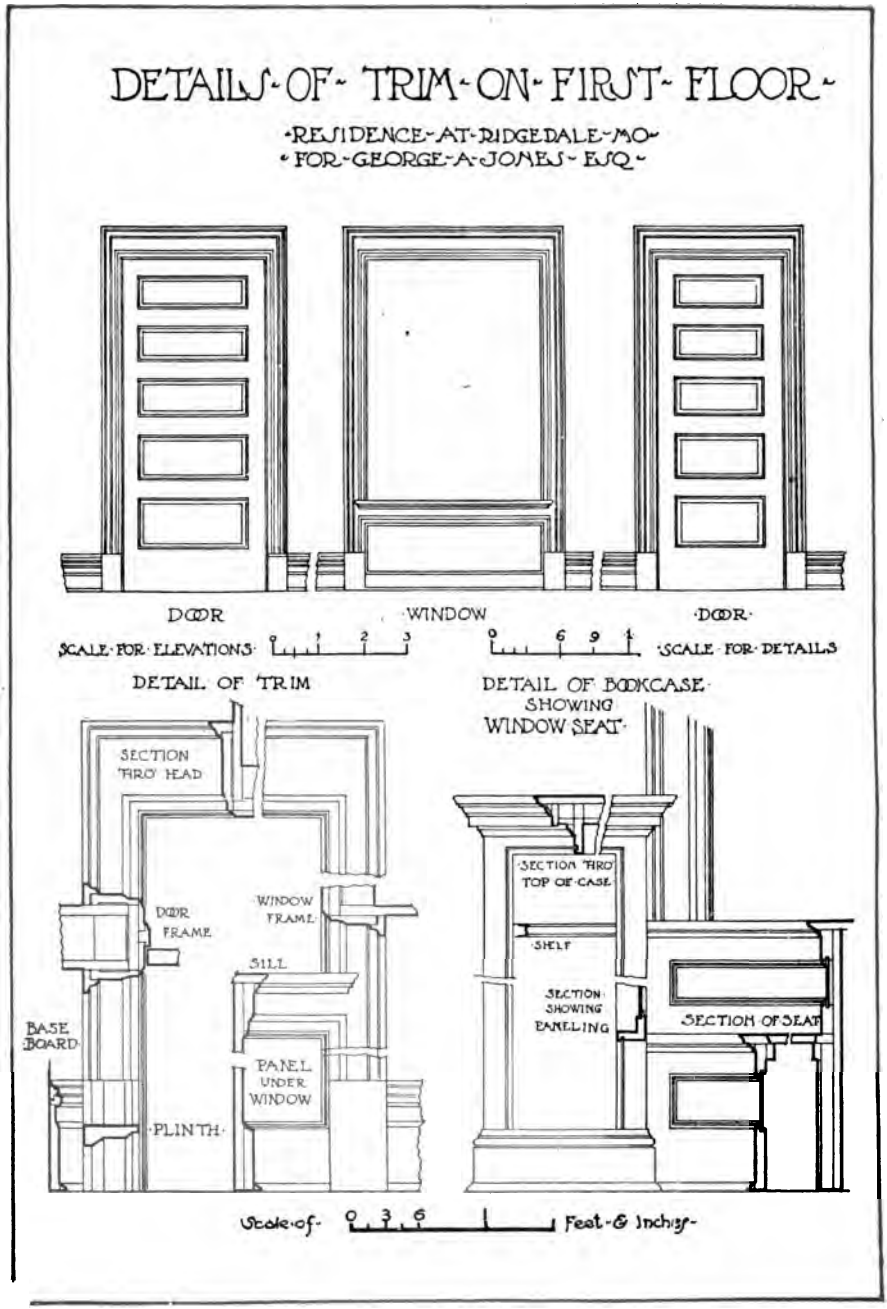


Fig. 49. Details of Trim on First Floor of the George A. Jones Residence

The sash are usually made one and three-quarters inches thick, for house construction; sometimes, in less expensive work, they are made one and one-half inches thick, and, for cheap cellar windows, one and one-quarter inches thick. For plate glass they should not be less than one and three-quarter inches thick; and for important work, they are usually two and one-quarter inches thick. Frames may be veneered on the inside, to match the other interior finish.

Porch and Front Entrance. For detail of these, see Fig. 48.

Trim on First Floor. For detail, see Fig. 49.

Uniform Titles for Drawings. Fig. 50 shows a scheme for a uniform title to be use on working drawings. This may be made as a rubber stamp, the name of the drawing being lettered in, the name of the

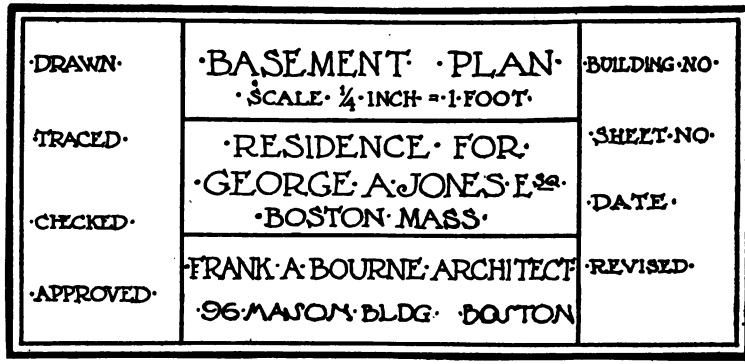


Fig. 50.

building being set up in rubber type, and the remainder being permanent. This stamp should be put on the drawing whenever it is started, a rubber dating stamp being used to give the date of beginning; the building number and sheet number should be recorded in the drawing book. The architect or draftsman who lays out the drawing puts his initials under the word "Drawn;" the draftsman who finishes it puts his initials under the word "Traced;" another puts his initials under the word "Checked," with the date; and finally the architect adds his initials and date after the drawings are ready to go out of the office. On the lower right-hand corner is a space where date of any revision may be entered. This stamp may be made four and seven-eighths inches long, so that it can be used on a 3 by 5 index card, for the drawing record; and also on a postal card, for a receipt to be signed by the con-

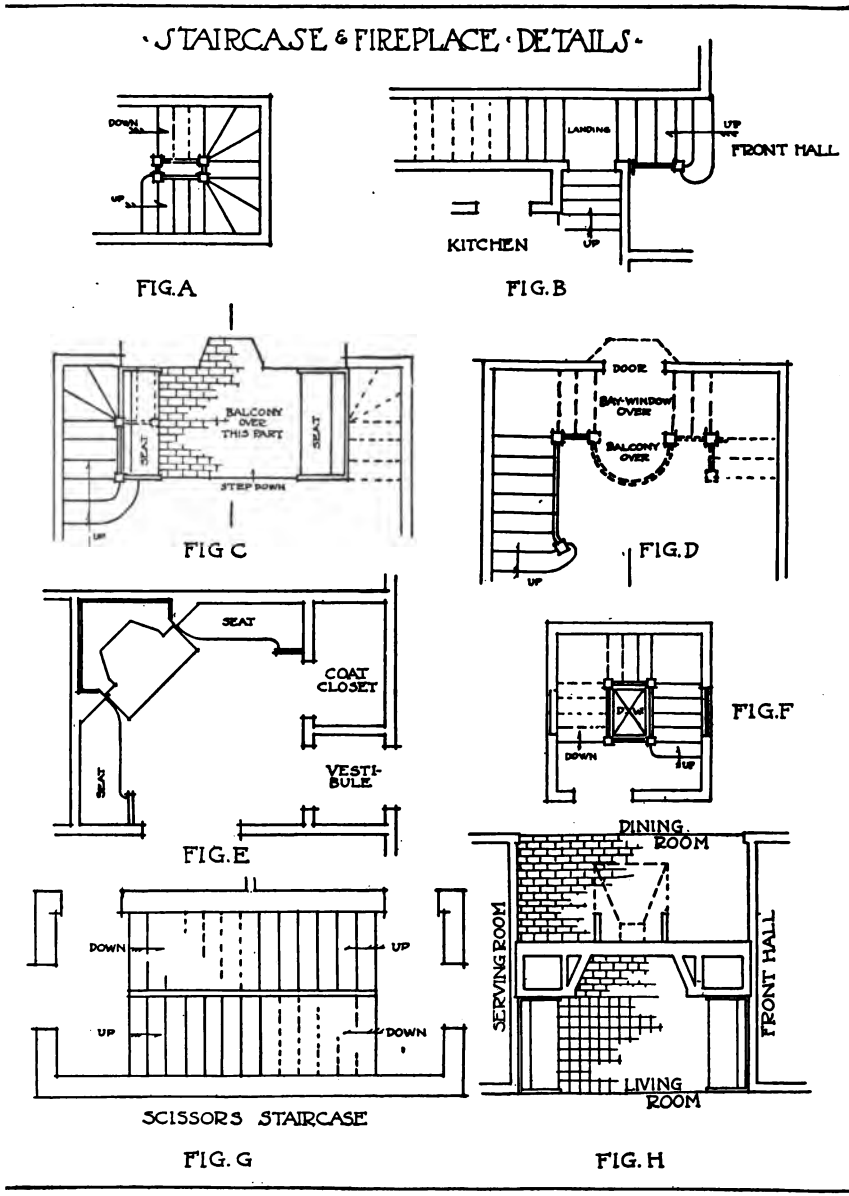


Fig. 51. Staircase and Fireplace Details for the George A. Jones Residence

tractor on receiving the drawing, or for any other memoranda in regard to drawings.

Staircase and Fireplace Details. One of the best ways to prepare for the designing of buildings is to study and make memoranda of interesting plans and details. This is especially true in relation to house building, as well as to the planning of large buildings. Some of the most interesting sketch books are those filled with small-plan details which can be referred to and used in the same manner as window or door details could be used in designing elevations. Fig. 51 shows several such small drawings on one sheet.

Fig. A shows the usual way of working out a back staircase entirely enclosed between partitions, one staircase going down under the other. This is very compact, and may be worked out in wood or iron and between plaster or brick walls. The space may be larger or smaller than that shown. The width of stairs from the finished wall to center of rail should never be less than 2 feet 2 inches for the smallest staircase, and usually 2 feet 8 inches is employed for a back staircase. Sometimes the newel posts are brought together as one, making what is practically a circular staircase.

Fig. B shows a combination staircase; that is to say, the front staircase goes up to a landing, and then continues in any direction to the second floor. From this landing a door opens, leading down to the service part of the house, giving many of the advantages of a back staircase. with loss of only a small amount of space.

Fig. C gives an interesting combination of staircase and fireplace. The fireplace is one step below the general floor level; and the ceiling is kept lower than the general ceiling of the room, with a small staircase leading up to a mezzanine story, above the fireplace, which may be arranged to look down on the main floor of the room or may form a sort of gallery.

Fig. D shows a staircase going up to a landing which is carried out into a room as a balcony indicated by dotted lines. At this level a little bay window is carried out over an outside doorway below. As there are only eleven risers shown, it would be necessary in this case to have the landing made of plank laid flat, to get head room for the seat.

Fig. E shows a compact arrangement of hall, coat closet, and out-

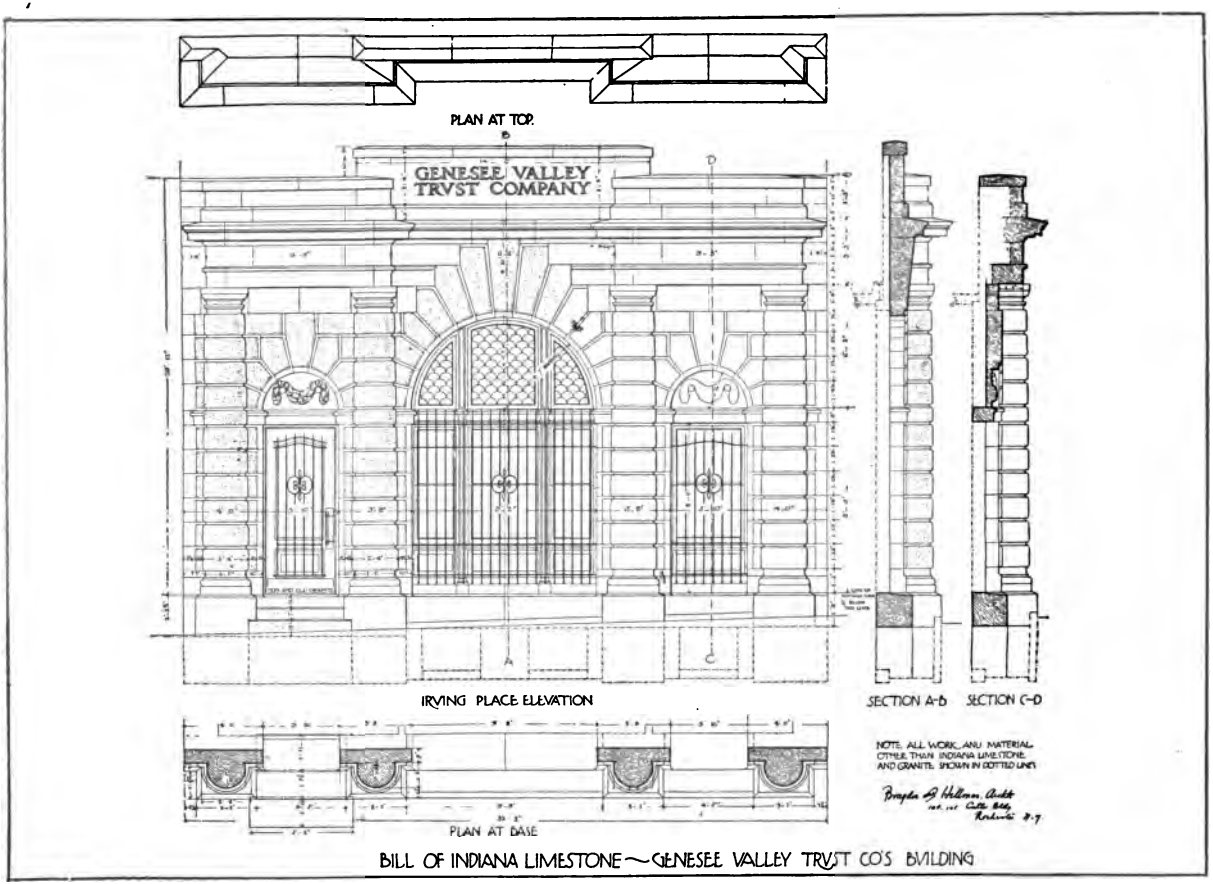


Fig. 52. Front Elevation and Details of Genesee Valley Trust Company Building

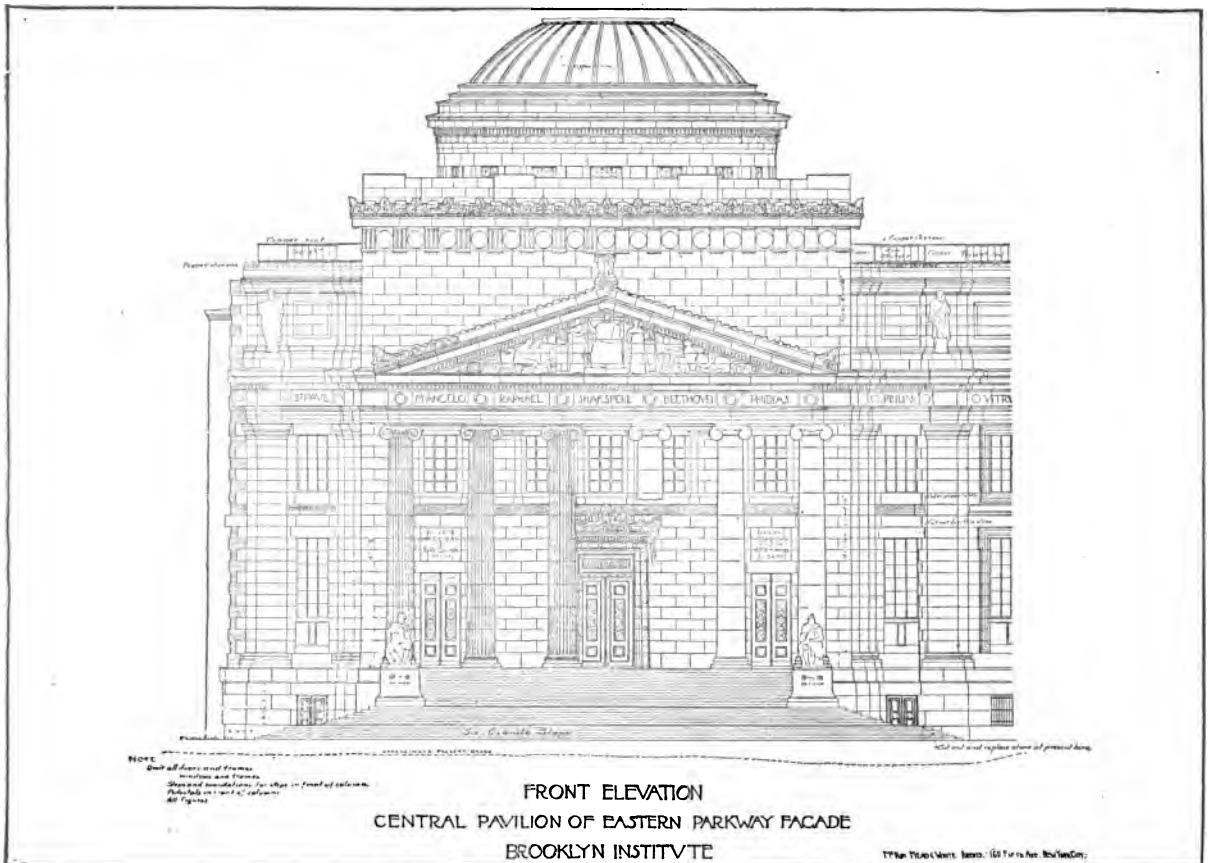


Fig. 53. Front Elevation of Brooklyn Institute

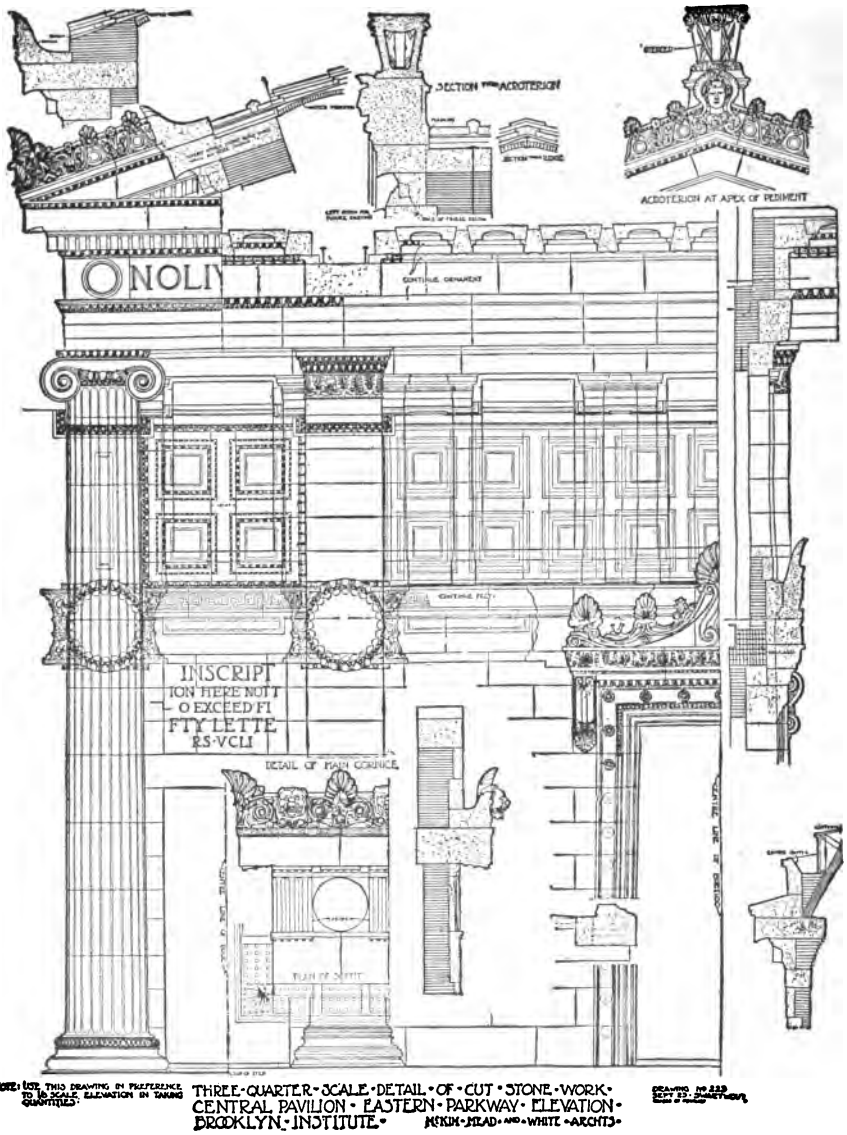


Fig. 54. Architectural Details of Brooklyn Institute

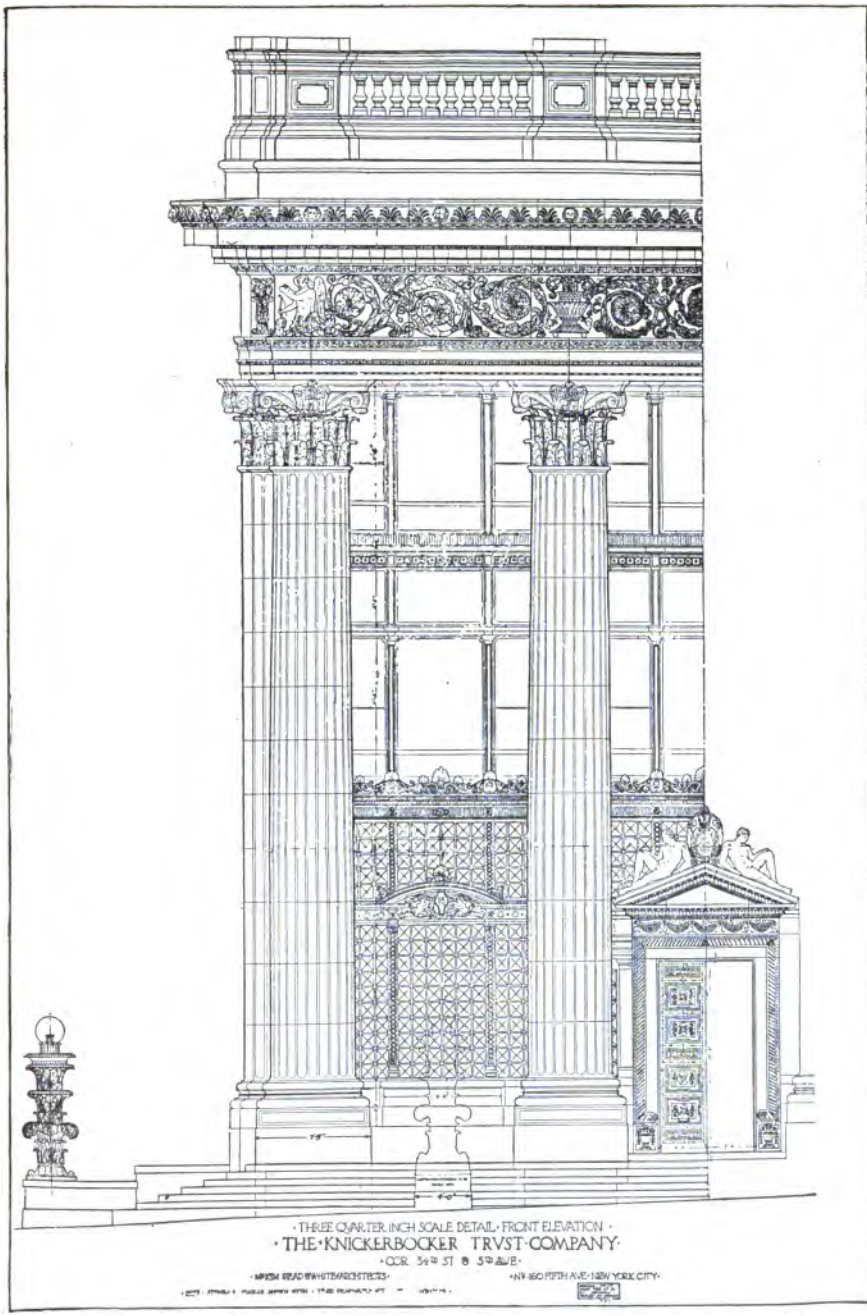

· THREE QUARTER INCH SCALE DETAIL · FRONT ELEVATION ·
· THE · KNICKERBOCKER TRVST · COMPANY ·
· COR 34TH ST & 5TH AVE ·
· MCKIM MEAD & WHITE ARCHITECTS ·
· NY · 160 FIFTH AVE · NEW YORK CITY ·

Fig. 55. Portion of Front Elevation of Knickerbocker Trust Company Building

side vestibule, with an interesting arrangement of the ingle-nook and fireplace, and seats each side.

Fig. F shows another arrangement of circular staircase differing from that shown in Fig. A, as it contains space for a service elevator or lift.

Fig. G shows a scissors staircase, which is sometimes used in double houses occupied by different families on each floor. This construction makes a saving of space, as the staircases may be placed under each other, while each family is able to go from floor to floor by its own private staircase. This arrangement is also sometimes used in schoolhouses, where there is height enough to have mezzanine toilet rooms at the landings, with separate stairways for boys and girls in the same given space on plan.

Fig. H shows an arrangement for the fireplace between dining room and living room where space is desired for closets or serving room between. On one side is built the ordinary fireplace with seats on each side, the tiling being carried out to the end of the seats; on the other side the hearth is carried out with brick floor, and the hood is carried out over this so that a basket of coals can be set directly on the brick floor. Sometimes the fire-basket is placed below the floor level, so that the surface comes about on a level with the floor.

Figs. 52 to 55 show working drawings of prominent architectural firms. It should be noted how carefully and clearly everything is drawn—from the lettering to the sculptured parts.

The preliminaries to starting a drawing, are:

Stretch a half sheet of Whatman's cold-pressed paper on your drawing board. While this is drying, sketch out rapidly with pencil, T-square, and triangles, on a piece of manila detail paper, the main lines of the proposed drawing. This will show the proper placing of the drawing, and save much erasing on the final sheet.

Sometimes tracing paper may be mounted over the Whatman's paper, and a place cut for making the final drawing; or the study may be made directly on the tracing paper over the final sheet, and then cut out and redrawn or transferred.

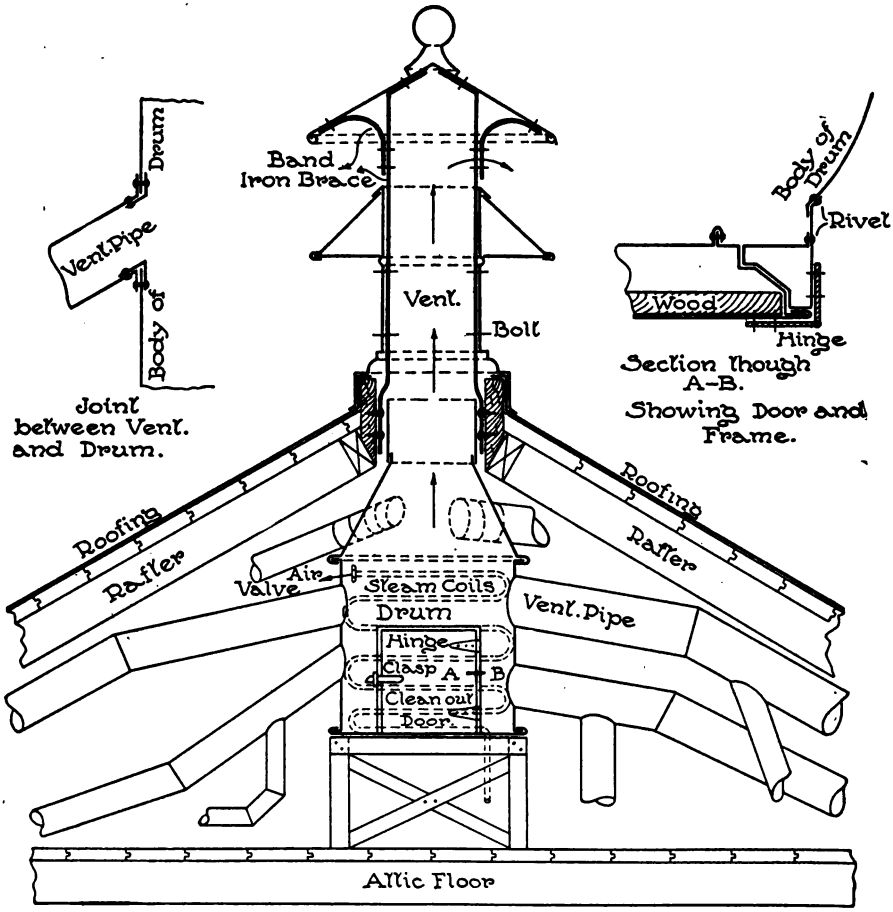
The paper required for the first drawing is, therefore:

One sheet Whatman's "Imperial" drawing paper.

One yard manila detail paper.

Several yards of Rowney's English tracing paper.

CONSTRUCTION DRAWING
SHOWING
SHEET METAL DRUM AND VENTILATOR IN VENTILATION WORK



Sectional view showing ventilation pipes connected to drum in attic also steam coils in drum to create suction.

SHEET METAL WORK

PART III

SKYLIGHT WORK

Where formerly skylights were constructed from wrought iron or wood, to-day in all the large cities they are being made of galvanized sheet iron and copper. Sheet metal skylights, having by their peculiar construction lightness and strength, are superior to iron and wooden lights; superior to iron lights, inasmuch as there is hardly any expansion or contraction of the metal to cause leaks or breakage of glass; and superior to wooden lights, because they are fire, water and condensation-proof, and being less clumsy, admit more light.

The small body of metal used in the construction of the bar and curb and the provisions which can be made to carry off the inside condensation, make sheet metal skylights superior to all others constructed from different material.

CONSTRUCTION

The construction of a sheet metal skylight is a very simple matter, if the patterns for the various intersections are properly developed. For example, the bar shown in Fig. 145 consists of a piece of sheet metal having the required stretchout and length, and bent by special machinery, or on the regular cornice brake, into the shape shown, which represents strength and rigidity with the least amount of weight. A A represent the condensation gutters to receive the condensation from the inside when the warm air strikes against the cold surface of the glass, while B B show the rabbets or glass-rest for the glass.

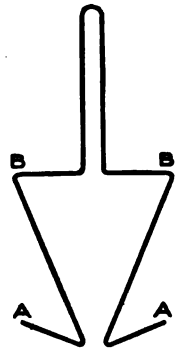


Fig. 145.

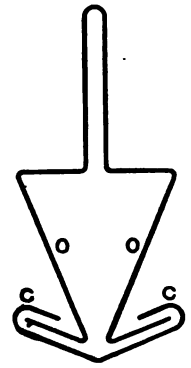


Fig. 146.

In Fig. 146, C C is a re-enforcing strip, which is used to hold the

two walls O O together and impart to it great rigidity. When skylight bars are required to bridge long spans, an internal core is made of sheet metal and placed as shown at A in Fig. 147, which adds to its weight-sustaining power. In this figure B B shows the glass laid on a bed of putty with the metal cap C C C, resting snugly against the glass, fastened in position by the rivet or bolt D D. Where a very large span is to be bridged a bar similar to that shown in Fig. 148 is used. A heavy core plate A made of ¼-inch thick metal is used, riveted or bolted to the bar at B and B. In construction, all the various bars terminate at the curb shown at A B C in Fig. 149, which is fastened to the wooden frame D E.

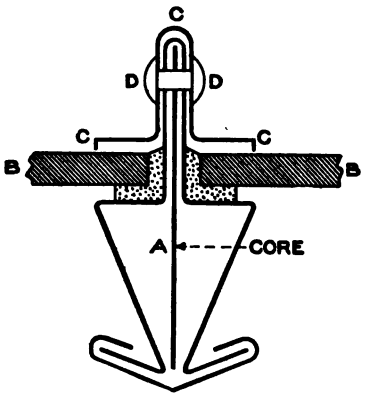


Fig. 147.

The condensation gutters C C in the bar *b*, carry the water into the internal gutter in the curb at *a*, thence to the outside through holes provided for this purpose at F F. In Fig. 150 is shown a sectional view of the construction of a double-pitched skylight. A shows the ridge bar with a core in the center and cap attached over the glass. B shows the cross bar or clip which is used in large skylights where it is impossible to get the glass in one length, and where the glass must be protected and leakage prevented by means of the cross bar, the gutter of which conducts the water into the gutter of the main bar, thence outside the curb as before explained. C is the frame generally made of wood or angle iron and covered by the metal roofer with flashing as shown at F. D shows the skylight bar with core showing the glass and cap in position. E is the metal curb against which the bars terminate, the condensation being let out through the holes shown.

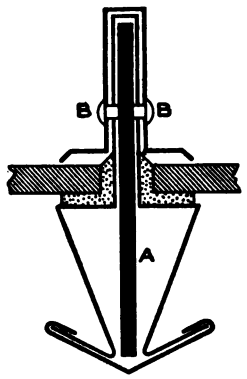


Fig. 148.

In constructing pitched skylights having double pitch, or being hipped, the pitch is usually one-third. In other words it is one-third

of the span. If a skylight were 12 feet wide and one-third pitch were required, the rise in the center would be one-third of 12, or 4 feet. When a flat skylight is made the pitch is usually built in the wood or iron frame and a flat skylight laid over it. The glass used in the construction of metallic skylights is usually $\frac{1}{4}$-inch rough or ribbed glass; but in some cases heavier glass is used.

If for any reason it is desired to know the weight of the various thickness of glass, the following table will prove valuable.

Weight of Rough Glass Per Square Foot.

Thickness in inches.

$\frac{1}{8}$. $\frac{3}{16}$. $\frac{1}{4}$. $\frac{3}{8}$. $\frac{1}{2}$. $\frac{5}{8}$. $\frac{3}{4}$. 1.

Weight in pounds.

2. $2\frac{1}{2}$. $3\frac{1}{2}$. 5. 7. $8\frac{1}{2}$. 10. $12\frac{1}{2}$.

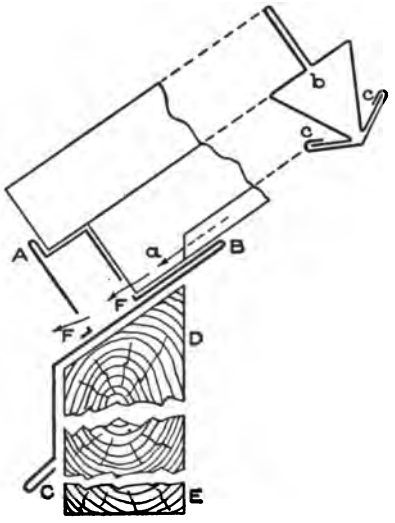


Fig. 149

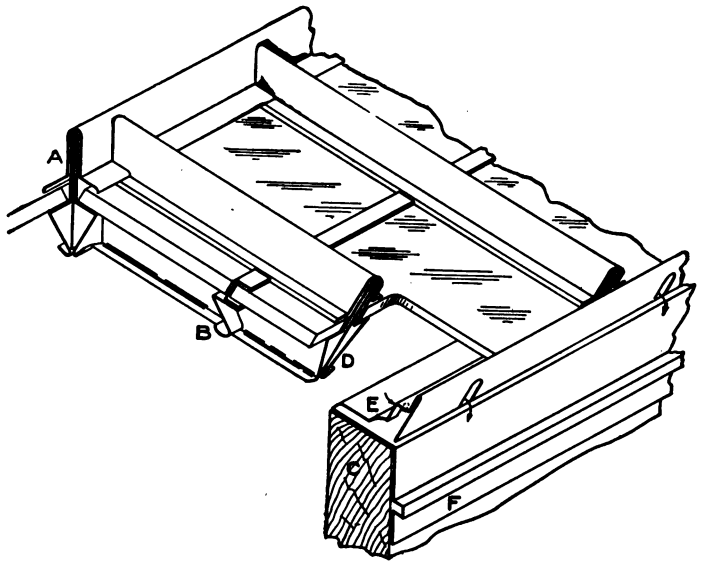


Fig. 150.

SHOP TOOLS

In the smaller shops the bars are cut with the hand shears and formed up on the ordinary cornice brake. In the larger shops, the strips required for the bars or curbs are cut on the large squaring shears, and the miters on the ends of these strips are cut on what is known as a miter cutter. This machine consists of eight foot presses on a single table, each press having a different set of dies for the purpose of cutting the various miters on the various bars. The bars are then formed on what is known as a Drop Press in which the bar can be formed in two operations to the length of 10 feet.

METHOD EMPLOYED IN OBTAINING THE PATTERNS

The method to be employed in developing the patterns for the various skylights is by parallel lines. If, however, a dome, conservatory or circular skylight is required, the blanks for the various curbs, bars, and ventilators are laid out by the rule given in the discussion of circular mouldings beginning on page 249.

VARIOUS SHAPES OF BARS

In addition to the shapes of bars shown in Figs. 145 to 148 inclusive, there is shown in Fig. 151 a plain bar without any condensation gutters, the joint being at A. B B represents the glass resting on the rabbets of the bar, while C shows another form of cap which covers

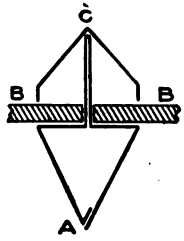


Fig. 151.

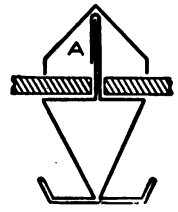


Fig. 152.

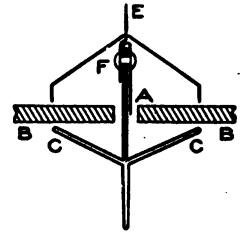


Fig. 153.

the joint between the bar and glass. Fig. 152 gives another form of bar in which the condensation gutters and bar are formed from one piece of metal with a locked hidden seam at A. Fig. 153 shows a bar on which no putty is required when glazing. It will be noticed that it is bent from one piece of metal with the seam at A, the glass B B resting on the combination rabbets and gutters C C. D is the cap which is fastened by means of the cleat E. These cleats are cut about ½-inch wide from soft 14-oz. copper, and riveted to the top of the bar

at F; then a slot is cut into the cap D as shown from *a* to *b* in Fig. 154; then the cap is pressed firmly onto the glass and the cleat E turned down which holds the cap in position.

When a skylight is constructed in which raising sashes are required, as shown in Fig. 155, half bars are required at the sides A and B, while the bars on each side of the sash to be raised are so constructed that a water-tight joint is obtained when closed. This is shown in Fig. 156, which is an enlarged section through A B in Fig. 155. Thus in Fig. 156, A A represents the two half bars with condensation gutters as shown, the locked seam taking place at B B. C C represent the two half bars for the raising sash with the caps D D attached to same, as shown, so that when the sash C C is closed, the caps

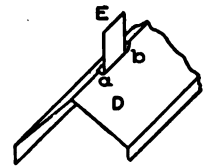


Fig. 154.

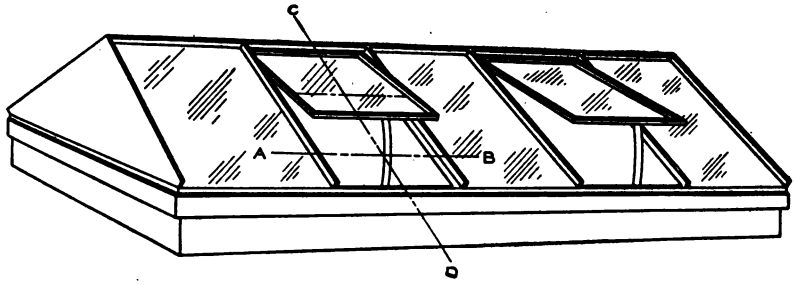


Fig. 155.

D D cover the joint between the glass E E and the stationary half bars. F F are the half caps soldered at *a a* to the bars C C which protect the joints between the glass H H and the bars C C.

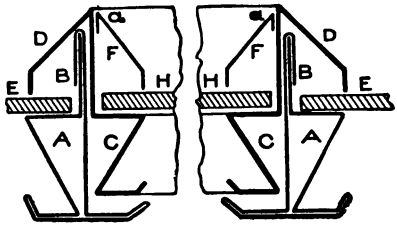


Fig. 156.

VARIOUS SHAPES OF CURBS

In Figs. 157, 158 and 159 are shown a few shapes of curbs which are used in connection with flat skylights. A in Fig. 157 shows the curb for the three sides of a flat skylight, formed in one piece with a joint at B, while C shows the cap, fastened as previously described. "A" shows the height at the lower end of the curb, which is made as high as the glass is thick and allows the water to run over. In Fig. 158, A is

another form of skylight formed in one piece and riveted at B; *a* shows the height at the lower end. In the previous figures the frame on which the metal curb rests is of wood, while in Fig. 159 the frame is

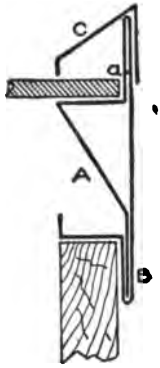


Fig. 157

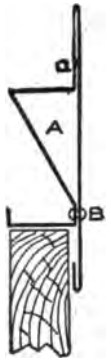


Fig. 158.

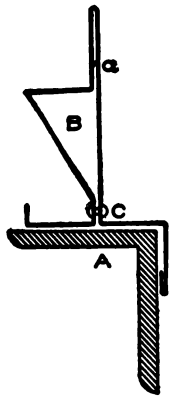


Fig. 159.

of angle iron shown at A. In this case the curb is slightly changed as shown at B; bent in one piece, and riveted at C. In Figs. 160, 161, and 162 are shown various shapes of curbs for pitched skylights in addition to that shown in Fig. 149. A in Fig. 160 shows a curb formed in one piece from *a* to *b* with a condensation hole or tube shown at B.

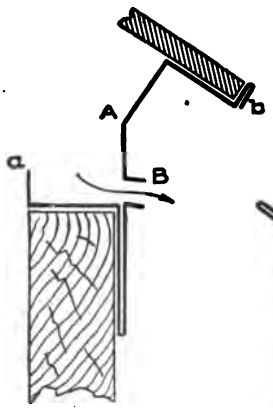


Fig. 160.

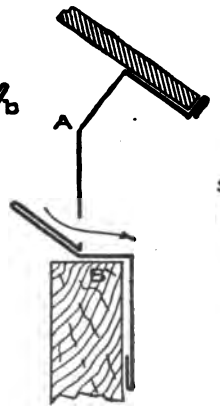


Fig. 161.

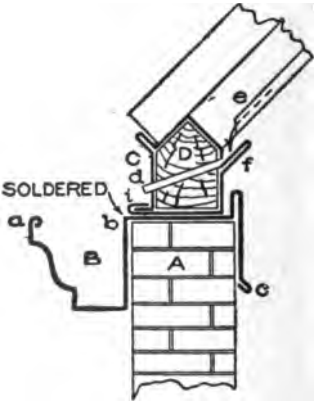


Fig. 162.

In Fig. 161 is shown a slightly modified shape A, with an offset to rest on the curb at B. When a skylight is to be placed over an opening whose walls are brick, a gutter is usually placed around the wall, as

shown in Fig. 162, in which A represents a section of the wall on which a gutter, B, is hung, formed from one piece of metal, as shown from *a* to *b* to *c*. On top of this the metal curb C is soldered, which is also formed from one piece with a lock seam at *i*. To stiffen this curb a wooden core is slipped inside as shown at D. From the inside condensation gutter *f* a 14-oz. copper tube runs through the curb, shown at *d*. The condensation from the gutter *e* in the bar, drips into the gutter *f*, out of the tube *d*, into the main gutter B, from which it is conveyed to the outside by a leader.

In Fig. 163 is shown an enlarged section of a raising sash, taken through C D in Fig. 155. A in Fig. 163 shows the ridge bar, B the lower curb and C D the side sections of the bars explained in connection with Fig. 156. E F in Fig. 163 shows the upper frame of the raising sash, fitting onto the half ridge bar A. On each raising sash, at the upper end two hinges H are riveted at E and I, which allow the sash to raise or close by means of a cord, rod, or gearings. J K shows the lower frame of the sash fitting over the curb B. Holes are punched at *a* to allow the condensation to escape into *b*, thence to the outside through C. Over the hinge H a hood or cap is placed which prevents leakage. Fig. 164 shows a section through A B in Fig. 167 and represents a hipped skylight having one-third pitch. By a skylight of one-third pitch is meant a skylight whose altitude or height A B, is equal to one-third of the span C D. If the skylight was to have a pitch of one-fourth or one-fifth, then the altitude A B would equal one-fourth or one-fifth respectively of the span C D.

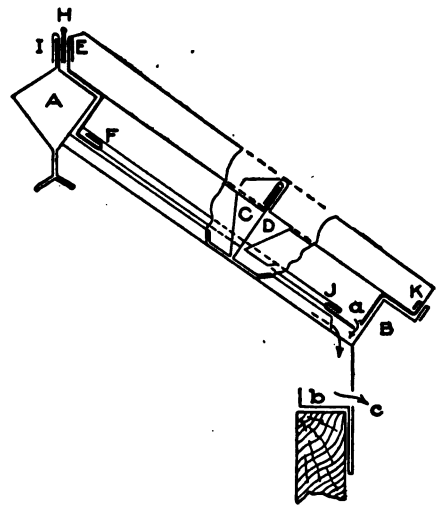


Fig. 163.

The illustration shows the construction of a hipped skylight with ridge ventilator which will be briefly described. C D is the curb; E E the inside ventilator; F F the outside ventilator forming a cap over the

glass at *a*. G shows the hood held in position by two cross braces H. J represents a section of the common bar on the rabbets of which the glass K K rests. L shows the condensation gutters on the bar J,

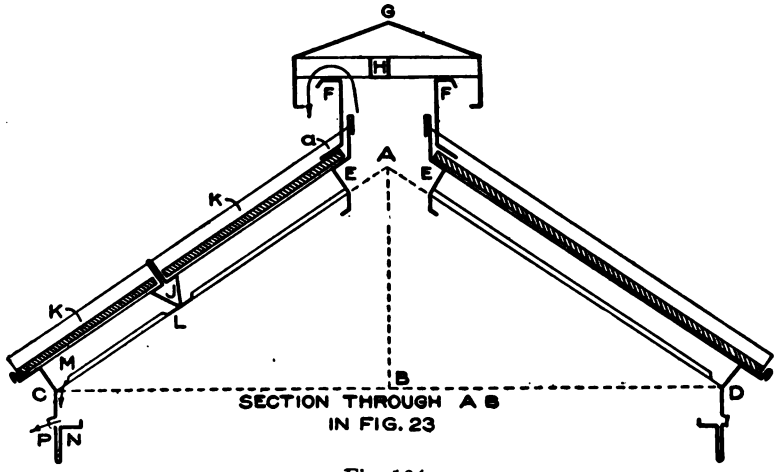


Fig. 164.

which are notched out as shown at M, thus allowing the drip to enter the gutter N and discharge through the tube P. The foul air escapes under the hood G as shown by the arrow.

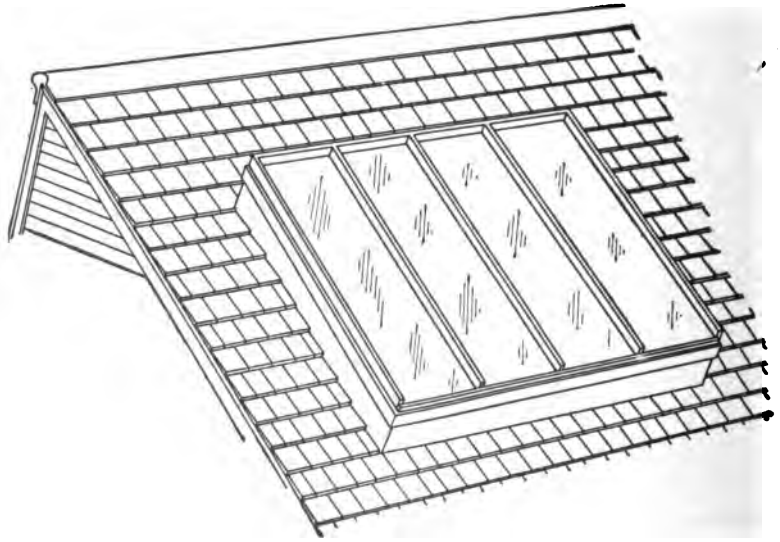


Fig. 165

VARIOUS STYLES OF SKYLIGHTS

In Fig. 165 is shown what is known as a single-pitch light, and is placed on a curb made by the carpenter which has the desired pitch.

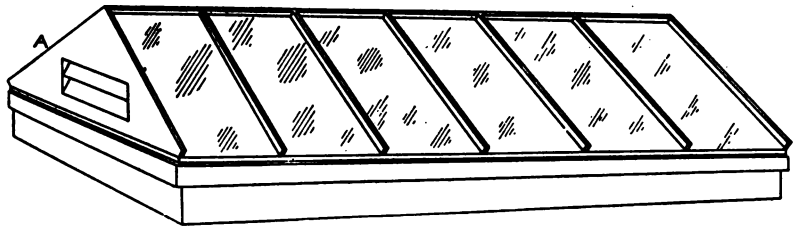


Fig. 166.

These skylights are chiefly used on steep roofs as shown in the illustration, and made to set on a wooden curbs pitching the same as the

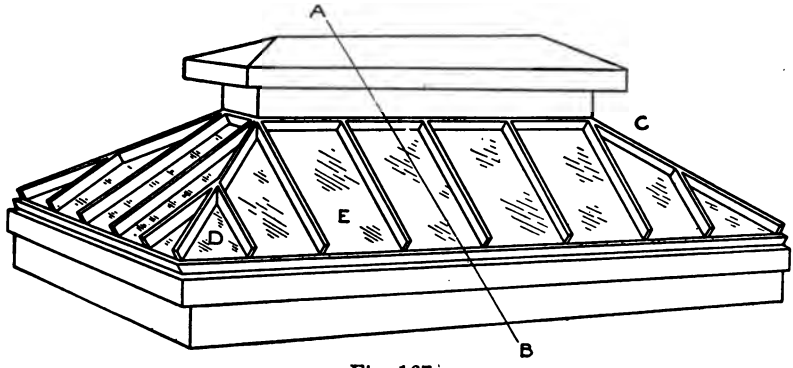


Fig. 167.

roof, the curb first being flashed. Ventilation is obtained by raising one or more lights by means of gearings, as shown in Fig. 155.

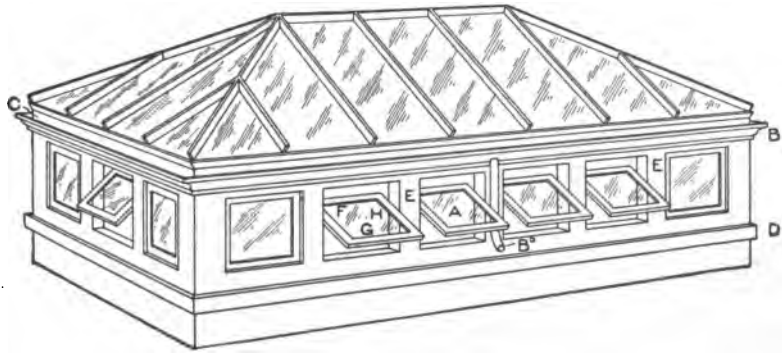


Fig. 168.

Fig. 166 shows a double-pitch skylight. Ventilation is obtained by placing louvres at each end as shown at A. Fig. 167 shows a skylight with a ridge ventilator. The corner bar C is called the hip bar; the small bar D, mitering against the corner bar, is called the jack bar, while E is called the common bar. Fig. 168 illustrates a hip monitor skylight with glazed opening sashes for ventilation. These sashes can be opened or closed separately, by means of gearings similar to those shown in Fig. 177 In Fig. 169 is shown the method of raising

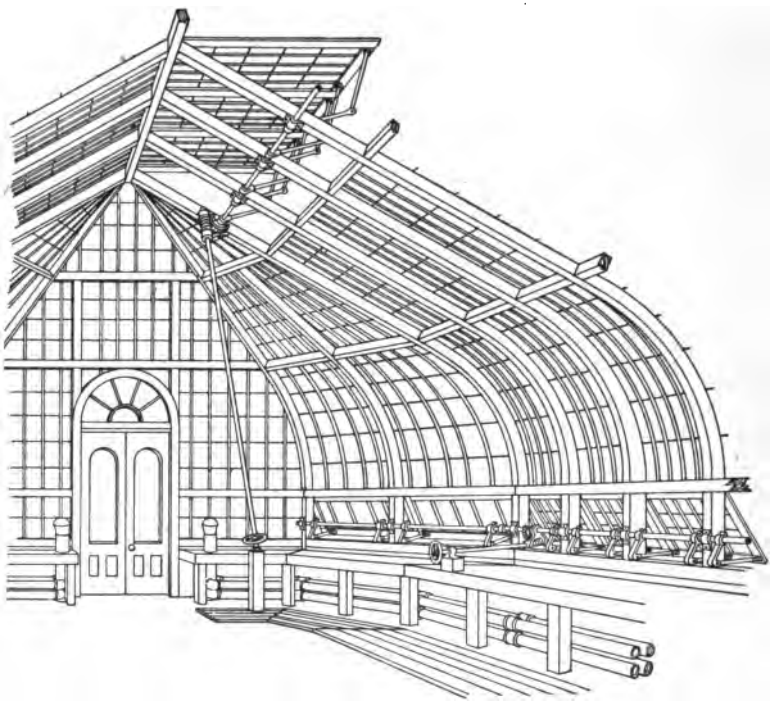


Fig. 169.

sashes in conservatories, greenhouses, etc., the same apparatus being applicable to both metal and wooden sashes. Fig. 170 shows a view of a photographer's skylight; if desired, the vertical sashes can be made to open.

In Fig. 171 is shown a flat extension skylight at the rear of a store or building. The upper side and ends are flashed into the brick work and made water-tight with waterproof cement, while the lower side rests on the rear wall to which it is fastened. In some cases the rear

gutter is of cast iron, put up by the iron worker, but it is usually made of No. 22 galvanized iron, or 20-oz. cold-rolled copper. To receive the bottom of the gutter and skylight, the wall should be covered by a wooden plate A, Fig. 172, about two inches thick, and another plank set edgeways flush with the inside of the wall, as shown at B. The two planks are not required when a cast iron gutter is used.

Fig. 173 shows a hipped skylight without a ridge ventilator, set on a metal curb in which louvres have been placed. These louvres may be made stationary or movable. When made movable, they are

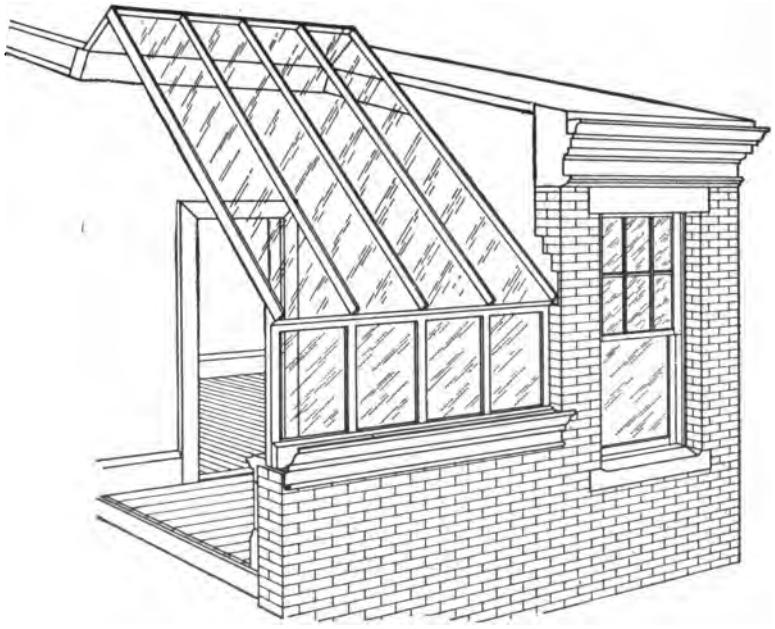


Fig. 170.

constructed as shown in Fig. 174, in which A shows a perspective view, B shows them closed, and C open. They are operated by the quadrants attached to the upright bars *a* and *b*, which in turn are pulled up and down by cords or chains worked from below. When a skylight has a very long span, as in Fig. 175, it is constructed as shown in Fig. 176, in which A represents a T-beam which can be trussed if necessary. This construction allows the water to escape from the bottom of the upper light to the outside of the top of the lower skylight, the curb C of the upper light fitting over the curb B of the lower light.

In Fig. 177 is shown the method of applying the gearings. A shows the side view of the metal or wooden sash partly opened, B the

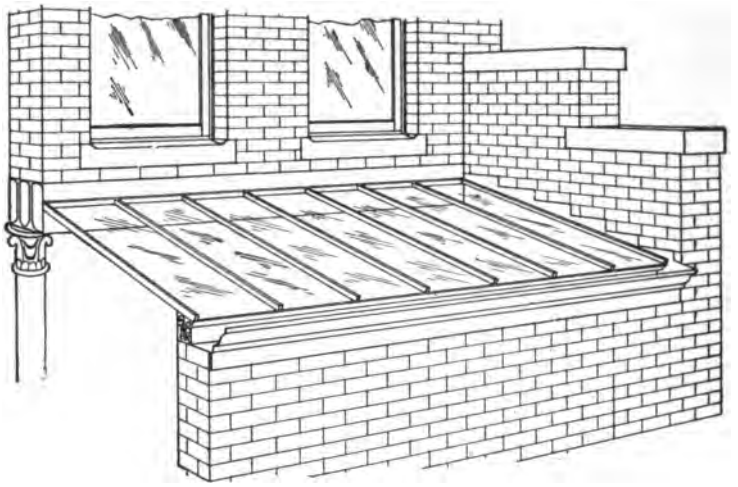


Fig. 171.

end of the main shaft, and C the binder that fastens the main shaft to the upright or rafter. D shows the quadrant wheel attached to main shaft and E is the worm wheel, geared to the quadrant D, communicating motion to the whole shaft. F is a hinged arm fastened to the main shaft B and hinged to the sash. By turning the hand-wheel the sash can be opened at any angle.

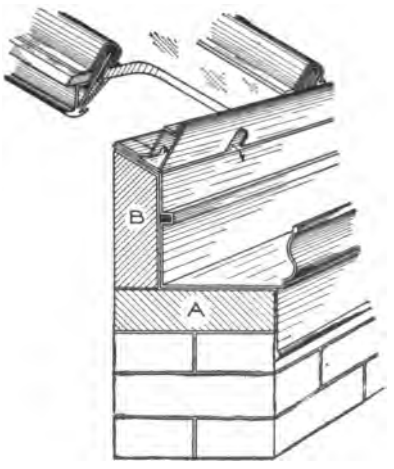


Fig. 172.

DEVELOPMENT OF PATTERNS FOR A HIPPED SKYLIGHT

The following illustrations and text will explain the principles involved in developing the patterns for the ventilator, curb, hip bar, common bar, jack bar, and cross bar or clip, in a hipped skylight. These principles are also applicable to any other form of light, whether flat, double-pitch, single-pitch, etc.

In Fig. 178 is shown a half section, a quarter plan, and a diagonal elevation of a hip bar, including the patterns for the curb, hip, jack, and common bars. The method of making these drawings will be explained in detail, so that the student who pays close attention

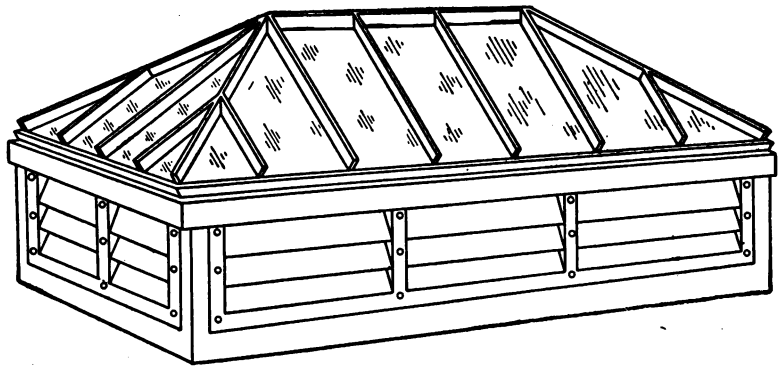


Fig. 173

will have no difficulty in laying out any patterns no matter what the pitch of the skylight may be, or what angle its plan may have.

First draw any center line as A B, at right angles to which lay off C 4′, equal to 12 inches. Assuming that the light is to have one-third

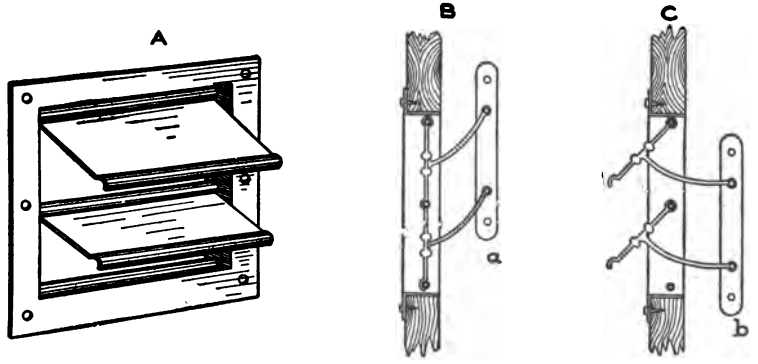


Fig. 174.

pitch, then make the distance C D equal to 8 inches which is one-third of 24 inches, and draw the slant line D 4.′ At right angles to D 4′ place a section of the common bar as shown by E, through which draw lines parallel to D 4′, intersecting the curb shown from *a* to *f* at the bottom and the inside section of the ventilator from F to G at the top. At

pleasure draw the section of the outside vent shown from *h* to *l* and the hood shown from *m* to *p*. X represents the section of the brace resting on *i j* to uphold the hood resting on it in the corner *o*. The condensa-

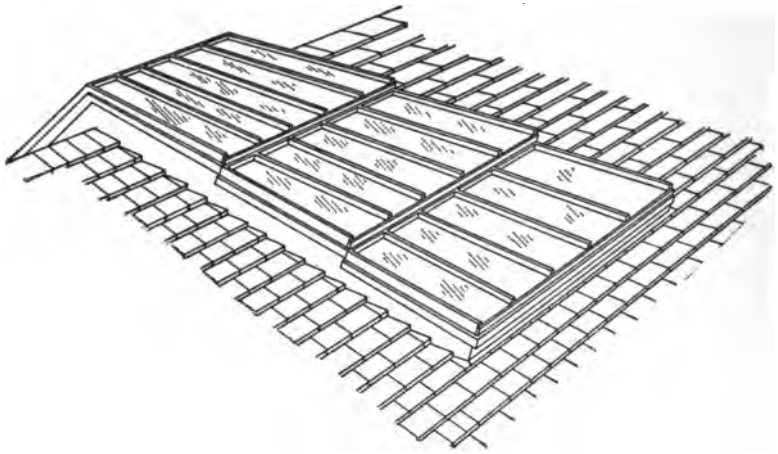


Fig. 175.

tion gutters of the common bar E are cut out at the bottom at 5′ 6′ which allows the drip to go into the gutter *d e f* of the curb and pass out of the opening indicated by the arrow. Number the corners of each half of the common bar section E as shown, from 1 to 6 on each side, through which draw lines parallel to D 4′ until they intersect the curb at the bottom as shown by similar numbers 1′ to 6′, and the inside ventilator at the top by similar figures 1″ to 6″. This completes the one half-section of the skylight. From this section the pattern for the common bar can be obtained without the plan, as follows:

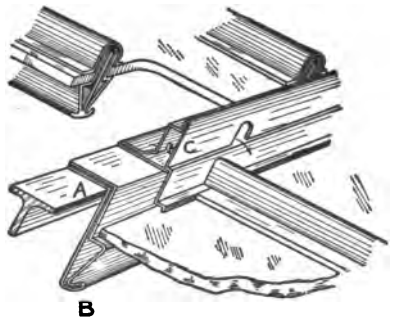


Fig. 176.

At right angles to D 4′ draw the line I J upon which place the stretchout of the section E as shown by similar figures on I J. Through these small figures, and at right angles to I J, draw lines, and intersect them by lines drawn at right angles to D 4′ from similarly numbered intersections 1′ to 6′ on the curb and 1″ to 6″ on the inside ventilator. Trace a line through points thus obtained; then A^1 B^1 C^1 D^1 will be the

pattern for the common bar in a hipped skylight. The same method would be employed if a pattern were developed for a flat or a double-pitch light. From this same half section the pattern for the curb is developed by taking the stretchout of the various corners in the curb, *a b* 3′ 4′ *c d e* and *f*, and placing them on the center line A B as shown by similar letters and figures. Through these divisions and at right angles to A B draw lines which intersect with lines drawn at right angles to C 4′ from similar points in the curb section *a f*. Trace a line through points thus obtained; then E^1 F^1 *f a* will be the half pattern for the curb shown in the half section. V represents the condensation hole to be punched into the pattern between each light of glass in the skylight. As the portion *c d* turns up on *c* 4′, use *r* as a center, and with

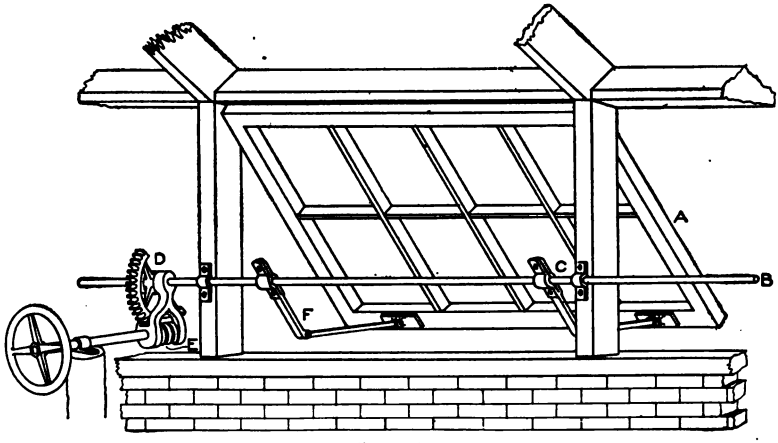


Fig. 177.

the radius *r s* strike the semicircle shown. Above this semicircle punch the hole V.

Before the patterns can be obtained for the hip and jack bars, a quarter plan view must be constructed which will give the points of intersections between the hip bar and curb, between the hip bar and vent, or ridge bar, and between the hip and jack bar. Therefore, from any point on the center line A B as K, draw K L at right angles to A B. As the skylight forms a right angle in plan, draw from K, at an angle of 45°, the hip or diagonal line K 1°. Take a tracing of the common bar section E with the various figures on same, and place it on the hip line K 1° in plan so that the points 1 4 come directly on the hip as shown by E^1. Through the various figures draw lines parallel to K 1°

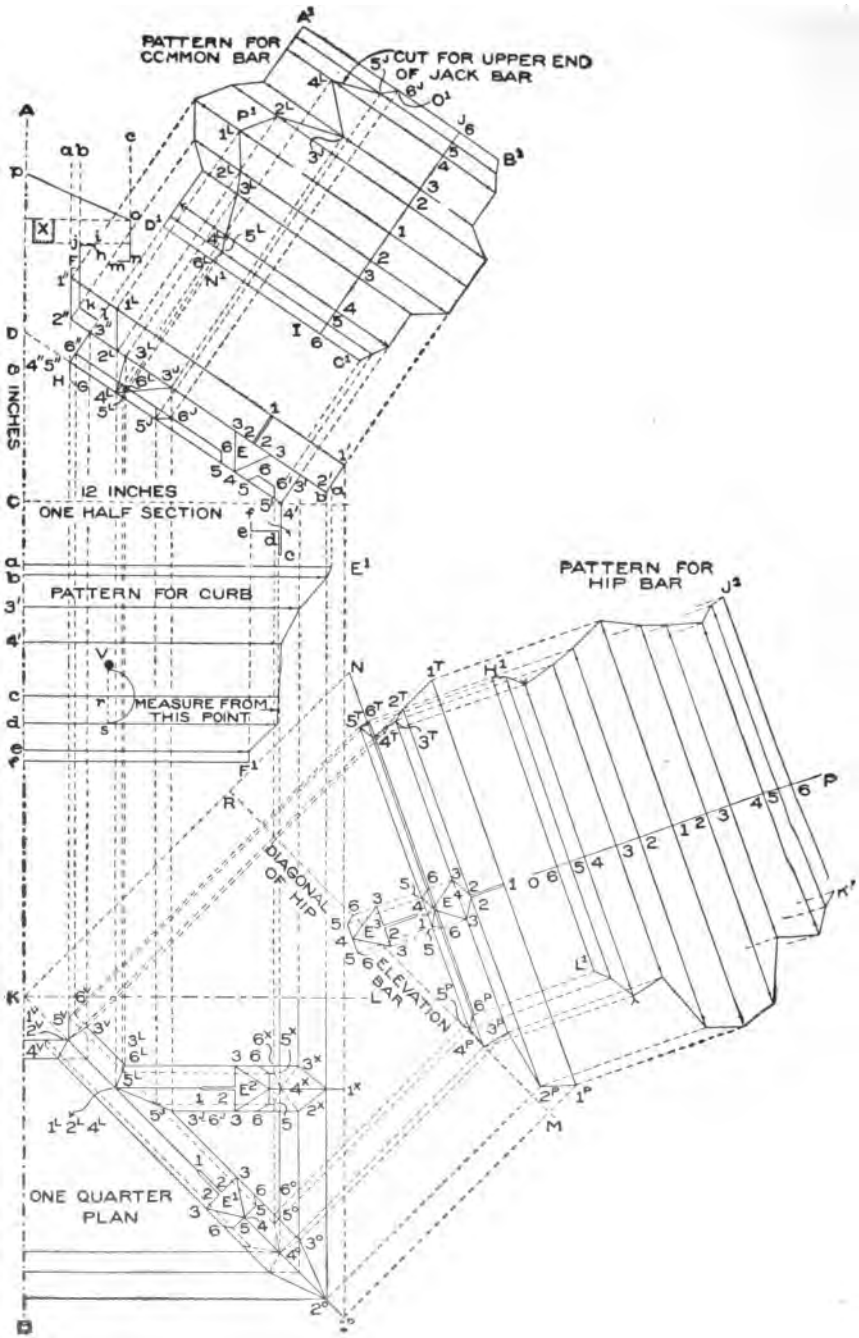

PATTERN FOR COMMON BAR
CUT FOR UPPER END OF JACK BAR
12 INCHES
ONE HALF SECTION
PATTERN FOR CURB
MEASURE FROM THIS POINT
PATTERN FOR HIP BAR
DIAGONAL OF HIP
ELEVATION
ONE QUARTER PLAN

Fig. 178.

one-half of which are intersected by vertical lines drawn parallel to A B from similar points of intersection 1′ to 6′ on the curb, and 1″ to 6″ on the ventilator in the half section, as shown respectively in plan by intersections 1° to 6° and 1^{v} to 6^{v}. Below the hip line K 1° trace the opposite intersection as shown. It should be understood that the section E^{1} in plan does not indicate the true profile of the hip bar (which must be obtained later), but is only placed there to give the horizontal distances in plan. In laying out the work in practice to full size, the upper half intersection of the hip bar in plan is all that is required. It will be noticed that the points of intersections in plan and one half section have similar numbers, and if the student will carefully follow each point the method of these projections will become apparent.

Having obtained the true points of intersections in plan the next step is to obtain a diagonal elevation of the hip bar, from which a true section of the hip bar and pattern are obtained. To do this draw any line as R M parallel to K 1°. This base line R M has the same elevation as the base line C 4′ has in the half section. From the various points 1° to 6° and 1^{v} to 6^{v} in plan, erect lines at right angles to K 1° crossing the line R M indefinitely. Now measuring in each and every instance from the line C 4′ in the half section take the various distances to points D 1″ 2″ 3″ 4″ 5″ and 6″ at the top, and to points 1′ 2′ 3′ 4′ 5′ and 6′ at the bottom, and place them in the diagonal elevation measuring in each and every instance from the line R M on the similarly numbered lines drawn from the plan, thus locating respectively the points N 1^{T} 2^{T} 3^{T} 4^{T} 5^{T} and 6^{T} at the top, and 1^{P} 2^{P} 3^{P} 4^{P} 5^{P} and 6^{P} at the bottom. Through the points thus obtained draw the miter lines 1^{T} to 6^{T} and 1^{P} to 6^{P} and connect the various points by lines as shown, which completes the diagonal elevation of the hip bar intersecting the curb and vent, or ridge. To obtain the true section of the hip bar, take a tracing of the common bar E or E^{1} and place it in the position shown by E^{3}, being careful to place the points 1 4 at right angles to 1^{T} 1^{P} as shown. From the various points in the section E^{3} at right angles to 1^{P} 1^{T} draw lines intersecting similarly numbered lines in the diagonal elevation as shown from 1 to 6 on either side. Connect these points as shown; then E^{4} will be the true profile of the hip bar. Note the difference in the two profiles; the normal E^{3} and the modified E^{4}.

Having obtained the true profile E^{4} the pattern for the hip bar is obtained by drawing the stretchout line O P at right angles 1^{T} 1^{P}.

Take the stretchout of the profile E^4 and place it on O P as shown by similar figures. Through these small figures and at right angles to O P draw lines which intersect by lines drawn at right angles to 1^T 1^P from similarly numbered points at top and bottom, thus obtaining the points of intersections shown. A line traced through the points thus obtained, as shown by H^1 J^1 K^1 L^1 will be the pattern for the hip bar.

For the pattern for the jack bar, take a tracing of the section of the common bar E and place it in the position in plan as shown by E^2 being careful to have the points 1 and 4 at right angles to the line 1^x 1^o. It is immaterial how far the section E^2 is placed from the corner 2^o as the intersection with the hip bar remains the same no matter how far the section is placed one way or the other. Through the various corners in the section E^2 draw lines at right angles to the line 1^o 1^x intersecting one half of the hip bar on similarly numbered lines as shown by the intersections 1^L 2^L 3^L 4^L 5^L 6^L and 1^L 2^J 3^J 4^L 5^J and 6^J; also intersecting the curb in plan at points 1^x to 6^x. The intersection between the jack bar and curb in plan is not necessary in the development of the pattern as the lower cut in the pattern for the common bar is the same as the lower cut in the pattern for the jack bar. However, the intersection is shown in plan to make a complete drawing. At right angles to the line of the jack bar in plan, and from the various intersections with the hip bar, erect lines intersecting similarly numbered lines in the section as shown. Thus from the various intersections shown from 1^L to 6^L in plan, erect vertical lines intersecting the bar in the half section at points shown from 1^L to 6^L. In similar manner from the various points of intersections 3^J, 5^J, and 6^J in plan, erect lines intersecting the bar in the half section at points shown by 3^J 5^J 6^J. Connect these points in the half section, as shown, which represents the line of joint in the section between the hip and jack bars.

For the pattern for the upper cut of the jack bar, the same stretchout can be used as that used for the common bar. Therefore, at right angles to D 4′ and from the various intersections 1^L 2^L 3^L 4^L 5^L and 6^L draw lines intersecting similar numbered lines in the pattern for the common bar as shown by similar figures. In similar manner from the various intersections 3^J 5^J and 6^J in the one half section, draw lines at right angles to D 4′ intersecting similarly numbered lines in the pattern as shown by 3^J 5^J and 6^J. Trace lines from point to point, then the

cut shown from N^1 to P^1 will represent the miter for that part shown in plan from 2^L to 6^L, and the cut shown from P^1 to O^1 in the pattern will represent the cut for that part shown in plan from 2^L to 6^J. The lower cut of the jack bar remains the same as that shown in the pattern.

The half pattern for the end of the hood is shown in Fig. 179, and is obtained as follows: Draw any vertical line as A B, upon which place the stretchout of the section of the hood *m n o p* in Fig. 178, as shown by similar letters *m n o p* on A B in Fig. 179. At right angles to A B and through the small letters draw lines, making them equal in length, (measuring from the line A B) to points having similar letters in Fig. 178, also measuring from the center line A B. Connect points shown in Fig. 179, which is the half pattern for the end of the hood. For the half pattern for the end of the outside ventilator, take the

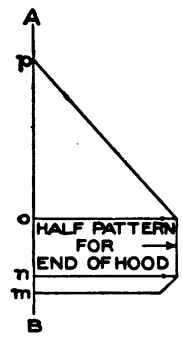


Fig. 179.

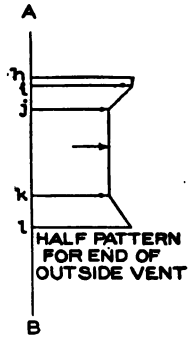


Fig. 180.

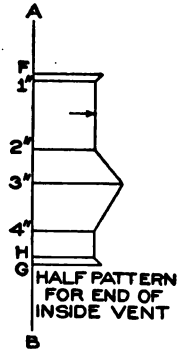


Fig. 181.

stretchout of *h i j k l* in Fig. 178 and place it on the vertical line A B in Fig. 180 as shown by similar letters, through which draw horizontal lines making them in length, measuring from A B, equal to similar letters in Fig. 178, also measuring from the center line A B. Connect the points as shown in Fig. 180 which is the desired half pattern. In Fig. 181 is shown the half pattern for the end of the inside ventilator, the stretchout of which is obtained from F 1″ 2″ 3″ 4″ H G in Fig. 178, the pattern being obtained as explained in connection with Figs. 179 and 180.

When a skylight is to be constructed on which the bars are of such lengths that the glass cannot be obtained in one length, and a cross bar or clip is required as shown by B, in Fig. 150, which miters against the main bar, the pattern for this intersecting cut is obtained as shown in

Fig. 182. Let A represent the section of the main bar, B the elevation of the cross bar, and C its section. Note how this cross bar is bent so that the water follows the direction of the arrow, causing no leaks because the upper glass *a* is bedded in putty, while the lower light *b* is capped by the top flange of the bar C (See Fig. 150). Number all of the corners of the section C as shown, from 1 to 8, from which points draw horizontal lines cutting the main bar A at points 1 to 8 as shown. At right angles to the lines in B draw the vertical line D E upon which

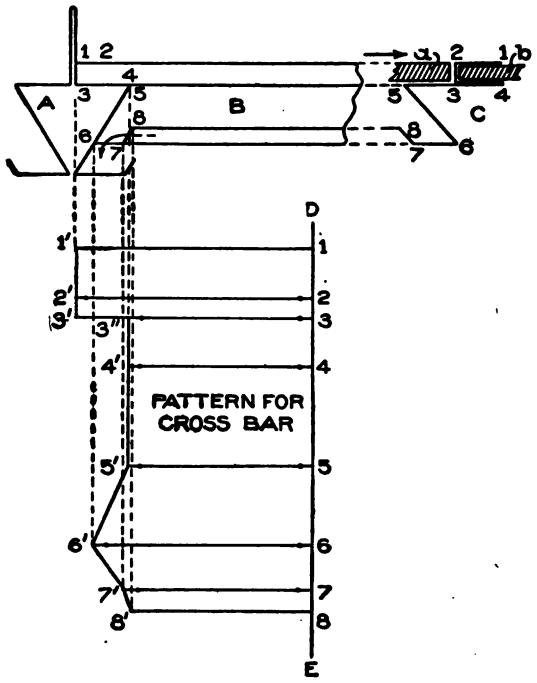


Fig. 182.

place the stretchout of the cross bar C, shown by similar figures, through which draw horizontal lines, intersecting them with lines drawn parallel to D E from similar numbered intersections against the main bar A, thus obtaining the points of intersections 1′ to 8′ in the pattern. Trace a line through points of intersections thus obtained which will be the pattern for the end cut of the cross bar.

In Fig. 183 is shown a carefully drawn working section of the turret sash shown in Fig. 168 at A. These sashes are operated by

means of cords, chains or gearings from the inside, the pivot on which they turn being shown by R S in Fig. 183. The method of obtaining the patterns for these sashes will be omitted, as they are only square and butt miters which the student will have no trouble in developing, providing he understands the construction. This will be made clear by the following explanation:

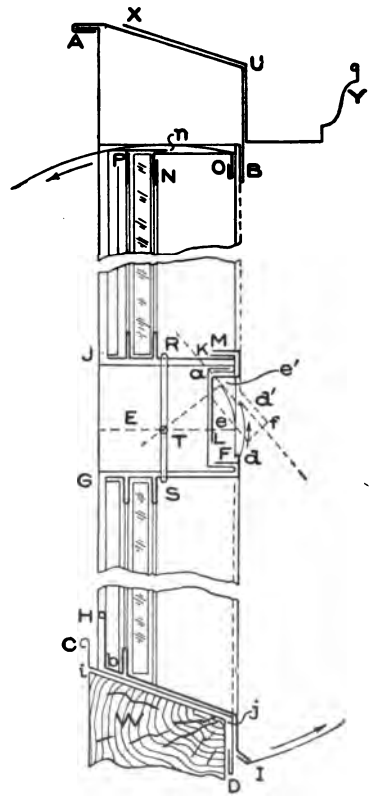


Fig. 183.

A B represents the upper part of the turret proper with a drip bent on same, as shown at B, against which the sashes close, and a double seam, as shown at A, which makes a tight joint, takes out the twist in bending, and avoids any soldering. This upper part A B is indicated by C in Fig. 168, over which the gutter B is placed as shown by X U Y in Fig. 183. C D represents the lower part of the turret proper or base, which fits over the wooden curb W, and is indicated by D in Fig. 168. E in Fig. 183 represents the mullion made from one piece of metal and double seamed at *a*. This mullion is joined to the top and bottom. The pattern for the top end of the mullion would simply show a square cut, while the pattern for the bottom would represent a butt miter against the slant line *i j*. Before forming up this mullion the holes should be punched in the sides to admit the pivot R S. These mullions are shown in position in Fig. 168 by E E, etc.

F G in Fig. 183 represents the section of the side of the sash below the pivot T. Notice that this lower half of the side of the sash has a lock attachment which hooks into the flange of the mullion E at F. While the side of the sash is bent in one piece, the upper half, above the pivot T, has the lock omitted as shown by J K. Thus when the sash opens, the upper half of the sides turn toward the inside as shown by

the arrow at the top, while the lower half swings outward as shown by the arrow at the bottom. When the lower half closes, it locks as shown at F, which makes a water-tight joint; but to obtain a water-tight joint for the upper half, a cap is used, partly shown by L M, into which the upper half of the side of the sash closes as shown at M. This cap is fastened to the upper part of the mullion E with a projecting hood *f* which is placed at the same angle as the sash will have when it is opened as shown by *e e'* and *d d'* or by the dotted lines.

The side of the sash just explained is shown in Fig. 168 at H. The pattern for the side of the sash has a square cut at the top, mitering with H I at the bottom, in Fig. 183, the same as a square miter. H I represents the section of the bottom of the sash. Note where the metal is doubled as at *b*, against which the glass rests in line with the rabbet on the side of the sash. A beaded edge is shown at H which stiffens it. This lower section is shown in Fig. 168 by G and has square cuts on both ends. N O in Fig. 183 shows the section of the top of the sash shown in Fig. 168 by F. The flange N in Fig. 183 is flush with the outside of the glass, thereby allowing the glass to slide into the grooves in the sides of the sash. After the glass is in position the angle P is tacked at *n*. A leader is attached to the gutter Y as shown by B° in Fig. 168. While the method of construction shown in Fig. 183 is generally employed, each shop has different methods; what we have aimed to give is the general construction in use, after knowing which, the student can plan his own construction to suit the conditions which are apt to arise.

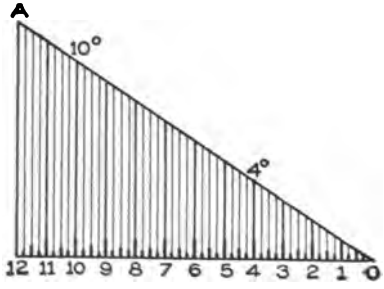


Fig. 184.

In the following illustrations, Figs. 184 to 187, it will be explained how to obtain the true lengths of the ventilator, ridge, hip, jack, and common bars in a hipped skylight, no matter what size the skylight may be. Using this rule only one set of patterns are required, as for example, those developed in connection with Figs. 178, 179, 180, and 181, which in this case has one-third pitch. If, however, a skylight was required whose pitch was different than one-third, a new set of patterns would have to be developed, to which the rule above mention-

ed would also be applicable for skylights of that particular pitch. Using this rule it should be understood that the size of the curb, or frame, forms the basis for all measurements, and that one of the lines or bends of the bar should meet the line of the curb as shown in Fig. 178, where the bottom of the bar E in the half section meets the line of the curb *c* 4′ at 4′, and the ridge at the top at 4′. Therefore when laying

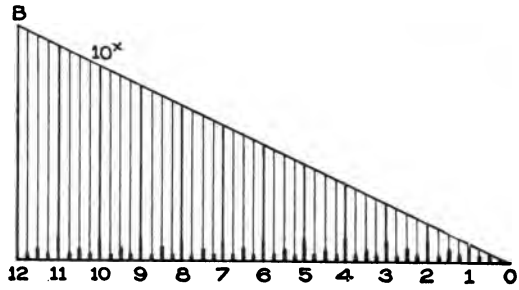


Fig. 185.

out the lengths of the bars, they would have to be measured on the line 4 of the bar E from 4′ to 4″ on the patterns, as will be explained as we proceed.

The first step is to prepare the triangles from which the lengths of the common and jack bars are obtained, also the lengths of the hip bars. After the drawings and patterns have been laid out full size according to the principles explained in Fig. 178, take a tracing of the triangle in the half section D C 4′ and place it as shown by A 12 O, in Fig. 184. Divide O 12, which will be 12 inches in full size, into quarter, half-inches, and inches, the same as on a 2-foot rule, as shown by the figures O to 12. From these divisions erect lines until they intersect the pitch A O which completes the triangle for obtaining the true lengths of jack and common bars for any size skylight. In similar manner take tracing of N R 4ᴿ in the diagonal elevation in Fig. 178 and place it as shown by B 12 O in Fig. 185. The length 12 O then becomes the base of the triangle for the hip bar in a skylight whose base of the triangle for the common and jack bars measures 12 inches

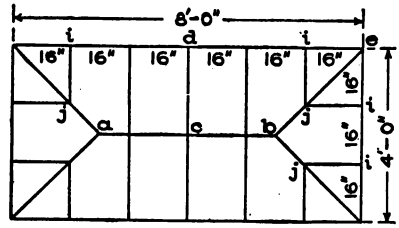


Fig. 186.

as shown in Fig. 184, the heights A 12 in Fig. 184 and B 12 in Fig. 185 being equal. Now divide 12 O in 12 equal spaces which will represent inches when obtaining the measurements for the hip bar. Divide each of the parts into quarter-inches as shown. From these devisions erect lines intersecting the hypothenuse or pitch line B O as shown.

To explain how these triangles are used in practice, Figs. 186 and 187 have been prepared, showing respectively a skylight without and with a ventilator whose curb measures 4 ft. x 8 ft. Three rules are used in connection with the triangles in Figs. 184 and 185, the comprehension of which will make clear all that follows.

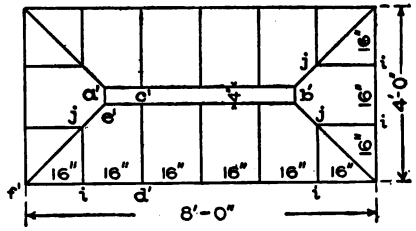


Fig. 187.

Rule 1. To obtain the length of the ridge bar in a skylight without a ventilator, as in Fig. 186, deduct the short side of the frame or curb from the long side.

Example: In Fig. 186, take 8 feet (long side of frame) — 4 feet (short side of frame) = 4 feet (length of ridge bar *a b*).

Rule 2. To find the length of the ventilator in a skylight deduct the short side of the frame from the long side and add the width of the desired ventilator (in this case 4 inches, as shown in Fig. 187).

Example: In Figure 187 take 8 feet (long side of frame) — 4 feet (short side of frame) = 4 feet. 4 feet + 4 inches (width of inside ventilator) = 4 feet 4 inches, (length of inside ventilator *a' b'*). To find the size of the outside ventilator *h l* and hood *m p* in Fig. 178 simply add twice the distance *a b* and *a c* respectively to the above size, 4 inches, and 4 feet 4 inches, which will give the widths and lengths of the outside vent and hood.

Rule 3. To find the lengths of either common or hip bar (in any size skylight) deduct the width of the ventilator, if any, from the length of the shortest side of frame and divide the remainder by two. Apply the length thus obtained on the base line of its respective triangle for common or hip bars and determine the true lengths of the desired bars, from the hypothenuse.

Example: As no ventilator is shown in Fig. 186, there will be nothing to deduct for it, and the operation is as follows: 4 feet (short-

est side of frame) ÷ 2 = 2 feet. We have now the length with which to proceed to the triangle for common and hip bars. Thus the length of the common bar *c d* will be equal to twice the amount of A O in Fig. 184, while the length of the hip bar *b e* in Fig. 186, will be equal to twice the amount of B O in Fig. 185. Referring to Figs. 186 and 187 the jack bars *i j* are spaced 16 inches, therefore, the length of the jack bar for 12 inches will equal A O in Fig. 184, and 4 inches equal to 4° O; both of which are added together for the full length.

The lengths of the common and hip bars will be shorter in Fig. 187 because a ventilator has been used, while in Fig. 186 a ridge bar was employed. To obtain the lengths of the common and hip bars in Fig. 187 use Rule 3: 48 inches (length of short side)—4 inches (width of inside ventilator) = 44 inches; and 44 inches ÷ 2 = 22 inches or 1 foot 10 inches. Then the length of the common bar *c' d'* measured with a rule will be equal to A O in Fig. 184 and 10° O added together, and the length of the hip bar *e' f'* in Fig. 187 will be equal to B O in Fig. 185 and 10ˣ O added together. Use the same method where fractional parts of an inch occur. In laying out the patterns according to these measurements use the cuts shown in Figs. 178, 179, 180, and 181, being careful to measure from the arrowpoints shown on each pattern.

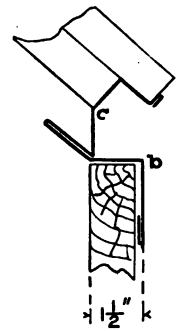


Fig. 188.

It will be noticed in Fig. 178 we always measure on line 4 in the patterns for the hip, common, and jack bars. This is done because the line 4 in the profiles E and E¹ come directly on the slant line of the triangles which were traced to Figs. 184 and 185 and from which the true lengths were obtained. Where a curb might be used, as shown in Fig. 188, which would bring the bottom line of the bar 1½ inches toward the inside of the frame *b*, all around, then instead of using the size of 4 x 8 feet as the basis of measurements deduct 3 inches on each side, making the basis of measurements 3 ft. 9 inches x 7 ft. 9 inches, and proceed as explained above.

ROOFING

A good metal covering on a roof is as important as a good foundation. There are various materials used for this purpose such as terne plate or what is commonly called roofing tin. The rigid body, or the base of roofing tin, consists of thin sheets of steel (black plates) that are coated with an alloy of tin and lead. Where a first-class job is desired soft and cold rolled copper should be used. The soft copper is generally used for cap flashing and allows itself to be dressed down well after the base flashing is in position. The cold-rolled or hard copper is used for the roof coverings. In some cases galvanized sheet iron or steel is employed. No matter whether tin, galvanized iron, or copper is employed the method of construction is the same, and will be explained as we proceed.

Another form of roofing is known as corrugated iron roofing, which consists of black or galvanized sheets, corrugated so as to secure strength and stiffness. Roofs having less than one-third pitch should be covered by what is known as flat-seam roofing, and should be covered (when tin or copper is used) with sheets 10 x 14 inches in size rather than with sheets 14 x 20 inches, because the larger number of seams stiffens the surface and prevents the rattling of the tin in stormy weather. Steep roofs should be covered by what is known as standing-seam roofing made from 14″ x 20″ tin or from 20″ x 28″. Before any metal is placed on a roof the roofer should see that the sheathing boards are well seasoned, dry and free from knots and nailed close together. Before laying the tin plate a good building paper, free from acid, should be laid on the sheathing, or the tin plate should be painted on the underside before laying. Corrugated iron is used for roofs and sides of buildings. It is usually laid directly upon the purlins in roofs, and held in place by means of clips of hoop iron, which encircle the purlins and are riveted to the corrugated iron about 12 inches apart. The method of constructing flat and double-seam roofing, also corrugated iron coverings, will be explained as we proceed.

TABLES

The following tables will prove useful in figuring the quantity of material required to cover a given number of square feet.

FLAT-SEAM ROOFING

Table showing quantity of 14 x 20-inch tin required to cover a given number of square feet with flat seam tin roofing. A sheet of 14 x 20 inches with with ½-inch edges measures, when edged or folded, 13 x 19 inches or 247 square inches. In the following all fractional parts of a sheet are counted a full sheet.

No. of sq. ft.	Sheets required	No. of sq. ft.	Sheets required	No. of sq. ft.	Sheets required	No. of sq. ft.	Sheets required
100	59	330	193	560	327	780	455
110	65	340	199	570	333	790	461
120	70	350	205	580	339	800	467
130	76	360	210	590	344	810	473
140	82	370	216	600	350	820	479
150	88	380	222	610	356	830	484
160	94	390	228	620	362	840	490
170	100	400	234	630	368	850	496
180	105	410	240	640	374	860	502
190	111	420	245	650	379	870	508
200	117	430	251	660	385	880	514
210	123	440	257	670	391	890	519
220	129	450	263	680	397	900	525
230	135	460	269	690	403	910	531
240	140	470	275	700	409	920	537
250	146	480	280	710	414	930	543
260	152	490	286	720	420	940	549
270	158	500	292	730	426	950	554
280	164	510	298	740	432	960	560
290	170	520	304	750	438	970	566
300	175	530	309	760	444	980	572
310	181	540	315	770	449	990	578
320	187	550	321				

1000 square feet, 583 sheets.

A box of 112 sheets 14 x 20 inches will cover approximately 192 square feet.

Example. How much 14 x 20 inch tin with ½-inch edges is required to cover a roof 20 feet x 84 feet? Take $20 \times 84 = 1{,}680$ square feet.

Referring to the table for Flat Seam Roofing, 1000 square feet require 583 sheets and 680 square feet require 397 sheets, making a total of 980 sheets.

It should be understood that this amount is figured on the basis of 247 square inches in an edged sheet, which will be a trifle less when the sheets are laid on the roof.

Example. What quantity of 20 x 28-inch tin will be required to lay a standing seam roof, measuring 37 feet long x 45 feet in width? Take $37 \times 45 = 1{,}665$ square feet, or 16 squares and 65 feet. Referring to the table for Standing Seam Roofing, 16 squares require 4 boxes and 48 sheets, and 65 feet require 20 sheets, making a total of 4 boxes and 68 sheets.

STANDING-SEAM ROOFING

Table showing the quantity of 20 × 28-inch tin in boxes, and sheets required to lay any given standing-seam roof.

SQ. FEET	SHEETS	SQUARES	SQ. FEET	BOXES	SHEETS	SQUARES	BOXES	SHEETS
1	1	.....	68	.....	21	35	9	77
2	1	.....	69	.....	21	36	9	108
3	1	.....	70	.....	22	37	10	27
4	2	.....	71	.....	22	38	10	58
5	2	.....	72	.....	22	39	10	89
6	2	.....	73	.....	22	40	11	8
7	3	.....	74	.....	23	41	11	39
8	3	.....	75	.....	23	42	11	70
9	3	.....	76	.....	23	43	11	101
10	4	.....	77	.....	24	44	12	20
11	4	.....	78	.....	24	45	12	51
12	4	.....	79	.....	24	46	12	82
13	4	.....	80	.....	25	47	13	1
14	5	.....	81	.....	25	48	13	32
15	5	.....	82	.....	25	49	13	63
16	5	.....	83	.....	25	50	13	94
17	6	.....	84	.....	26	51	14	13
18	6	.....	85	.....	26	52	14	44
19	6	.....	86	.....	26	53	14	75
20	7	.....	87	.....	27	54	14	106
21	7	.....	88	.....	27	55	15	25
22	7	.....	89	.....	27	56	15	56
23	7	.....	90	.....	28	57	15	87
24	8	.....	91	.....	28	58	16	6
25	8	.....	92	.....	28	59	16	37
26	8	.....	93	.....	28	60	16	68
27	9	.....	94	.....	29	61	16	99
28	9	.....	95	.....	29	62	17	18
29	9	.....	96	.....	29	63	17	49
30	10	.....	97	.....	30	64	17	80
31	10	.....	98	.....	30	65	17	111
32	10	.....	99	.....	30	66	18	30
33	10	.....	100	.....	31	67	18	61
34	11	1	.....	.....	31	68	18	92
35	11	2	.....	.....	62	69	19	11
36	11	3	.....	.....	93	70	19	42
37	12	4	.....	1	12	71	19	73
38	12	5	.....	1	43	72	19	104
39	12	6	.....	1	74	73	20	23
40	13	7	.....	1	105	74	20	54
41	13	8	.....	2	24	75	20	85
42	13	9	.....	2	55	76	21	4
43	13	10	.....	2	86	77	21	35
44	14	11	.....	3	5	78	21	66
45	14	12	.....	3	36	79	21	97
46	14	13	.....	3	67	80	22	16
47	15	14	.....	3	98	81	22	47
48	15	15	.....	4	17	82	22	78
49	15	16	.....	4	48	83	22	109
50	16	17	.....	4	79	84	23	28
51	16	18	.....	4	110	85	23	59
52	16	19	.....	5	29	86	23	90
53	16	20	.....	5	60	87	24	9
54	17	21	.....	5	91	88	24	40
55	17	22	.....	6	10	89	24	71
56	17	23	.....	6	41	90	24	102
57	18	24	.....	6	72	91	25	21
58	18	25	.....	6	103	92	25	52
59	18	26	.....	7	22	93	25	83
60	19	27	.....	7	53	94	26	2
61	19	28	.....	7	84	95	26	33
62	19	29	.....	8	3	96	26	64
63	19	30	.....	8	34	97	26	95
64	20	31	.....	8	65	98	27	14
65	20	32	.....	8	96	99	27	45
66	20	33	.....	9	15	100	27	76
67	21	34	.....	9	46			

Size of sheet before working, 20 × 28 inches. Exposed on roof 27×17¾ inches.
Square inches per sheet exposed 479¼ inches. Sheets per box 112.

NET WEIGHT PER BOX TIN PLATES
Basis 14 × 20, 112

Trade term . . .		80-lb.	85-lb.	90-lb.	95-lb.	100-lb.	IC	IXL	IX	IXX	IXXX	IXXX
Weight per box, lb.		80	85	90	95	100	107	128	135	155	175	195
Size of sheets	Sheets per box											
10 x 14	225	80	85	90	95	100	107	128	135	155	175	195
14 x 20	112	80	85	90	95	100	107	128	135	155	175	195
20 x 28	112	160	170	180	190	200	214	256	270	310	350	390
10 x 20	225	114	121	129	136	143	153	183	193	221	250	279
11 x 22	225	138	147	156	164	172	184	232	234	268	302	337
11½ x 23	225	151	161	170	179	189	202	242	255	293	331	368
12 x 12	225	82	87	93	98	103	110	132	139	159	180	201
12 x 24	112	82	87	93	98	103	110	132	139	159	180	201
13 x 13	225	97	103	109	115	121	129	154	163	187	211	235
13 x 26	112	97	103	109	115	121	129	154	163	187	211	235
14 x 14	225	112	119	126	133	140	150	179	189	217	245	273
14 x 28	112	112	119	126	133	140	160	179	189	217	245	273
15 x 15	225	129	137	145	153	161	172	206	217	249	281	313
16 x 16	225	146	155	165	174	183	196	234	247	283	320	357
17 x 17	225	165	175	186	196	206	221	264	279	320	361	403
18 x 18	112	93	98	104	110	116	124	148	156	179	202	226
19 x 19	112	103	110	116	122	129	138	165	174	200	226	251
20 x 20	112	114	121	129	136	143	153	183	193	221	250	279
21 x 21	112	126	134	142	150	158	169	202	213	244	276	307
22 x 22	112	138	147	156	164	172	184	221	234	268	302	337
23 x 23	112	151	161	170	179	189	202	242	255	293	331	368
24 x 24	112	164	175	185	195	204	220	263	278	319	360	401
26 x 26	112	193	205	217	229	241	258	309	326	374	422	471
16 x 20	112	91	97	103	109	114	122	146	154	177	200	223
14 x 31	112	124	132	140	147	155	166	198	209	240	271	302
11¼ x 22¾	112	73	78	82	87	91	98					
13¼ x 17¾	112	60	71	76	80	84	90					
13¼ x 19¼	112	73	77	82	87	91	97					
13½ x 19½	112	75	80	85	89	94	100					
13½ x 19¾	112	76	81	86	90	95	102					
14 x 18¾	124	83	88	93	98	103	110					
14 x 19¼	120	83	88	93	98	103	110					
14 x 21	112	84	89	95	100	105	112					
14 x 22	112	88	94	99	105	110	118					
14 x 22¼	112	89	95	100	106	111	119					
15½ x 23	112	102	108	115	121	127	136					

STANDARD WEIGHTS AND GAUGES OF TIN PLATES

Trade term	65-lb.	70-lb.	75-lb.	80-lb.	85-lb.	90-lb.	95-lb.	100-lb.
Nearest wire gauge No.	35	35	34	33	32	31	31	30
Weight, square foot, lb.	.298	.322	.345	.367	.390	.413	.436	.459
Weight, box, 14 x 20, lb.	65	70	75	80	85	90	95	100

Trade term	IC	IXL	IX	IXX	IXXX	IXXXX	IXXXXX
Nearest wire gauge No.	30	28	28	27	26	25	24
Weight, square foot, lb.	.491	.588	.619	.712	.803	895	.987
Weight, box, 14 x 20, lb.	107	128	135	155	175	195	215

	IC 14 x 20	IC 20 x 28	IX 14 x 20	IX 20 x 28
Black plates before coating .. weight per 112 sheets	lb. 95 to 100	lb. 190 to 200	lb. 125 to 130	lb. 250 to 260
When coated the plates weigh per 112 sheets	115 to 120	230 to 240	145 to 150	290 to 300

OTHER FORMS OF METAL ROOFING

There is another form of roofing known as metal slates and shingles, pressed in various geometrical designs with water-tight lock attachments so that no solder is required in laying the roof. Fig. 189 shows the general shape of these metal shingles which are made from tin, galvanized iron, and copper, the dots *a a a a* representing the holes for nailing to the wood sheathing. In Fig. 190, A represents the side lock, showing the first operation in laying the metal slate or shingle on a roof, *a* representing the nail. B, in the same figure, shows the metal slate or shingle in position covering the nail *b*, the valley *c* of the bottom slate allowing the water, if any, to flow over the next lower slate as in A in Fig. 189.

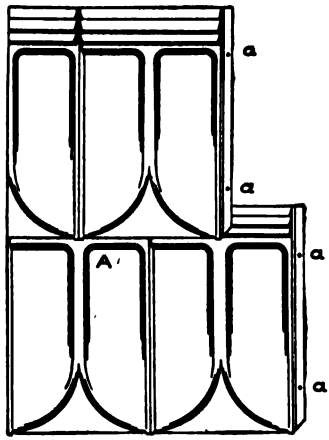


Fig. 189.

In Fig. 191 is shown the bottom slate A covered by the top slate B, the ridges *a a a* keeping the water from backing up. Fig. 192 shows the style of roof on which these shingles are employed, that is, on steep roofs. Note the construction of the ridge roll, A and B in Fig. 192, which is first nailed in position at *a a* etc., after which the shingles B are slipped under the lock *c*. Fig. 193 shows a roll hip covering which is laid from the top downward, the lower end of the hip having a projection piece for nailing at *a*, over which the top end of the next piece is inserted, thus

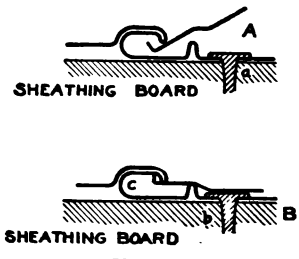


Fig. 190.

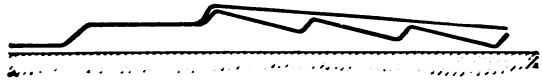


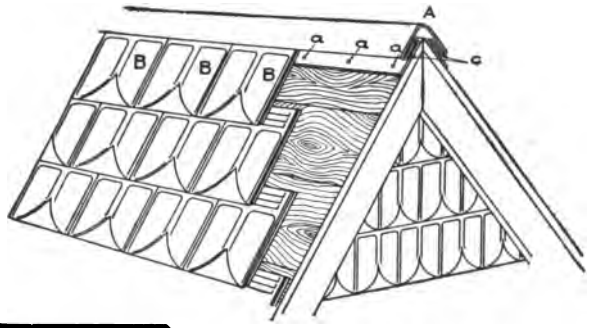
Fig. 191.

covering and concealing the nails. Fig. 194 represents a perspective view of a valley with metal slates, showing how the slates A are locked to the fold in the valley B. There are many other forms of

metal shingles, but the shapes shown herewith are known as the Cortright patents.

TOOLS REQUIRED

Fig. 195 shows the various hand tools required by the metal roofer; starting at the left we have the soldering copper, mallet, scraper,



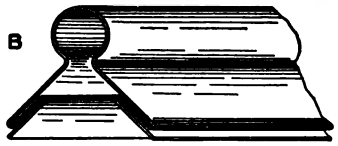


Fig. 192.

stretch-awl, shears, hammer, and dividers. In addition to these hand tools a notching machine is required for cutting off the corners of the

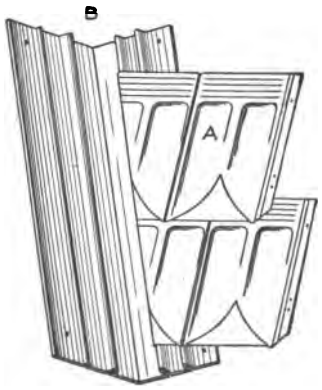


Fig. 194.

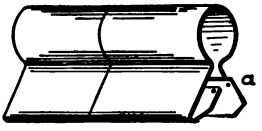


Fig. 193.

sheets, and roofing folders are required for edging the sheets in flat-seam roofing, and hand double seamer and roofing tongs for standing-seam roofing. The roofing double seamer and squeezing tongs can be used for standing-seam roofing (in place of the hand double seamer), which allow the operator to stand in an upright position if the roof is not too steep.

ROOF MENSURATION

While some mechanics understand thoroughly the methods of

laying the various kinds of roofing, there are some, however, who do not understand how to figure from architects' or scale drawings the amount of material required to cover a given surface in a flat, irregular shaped, or hipped roof. The modern house with its gables and va-

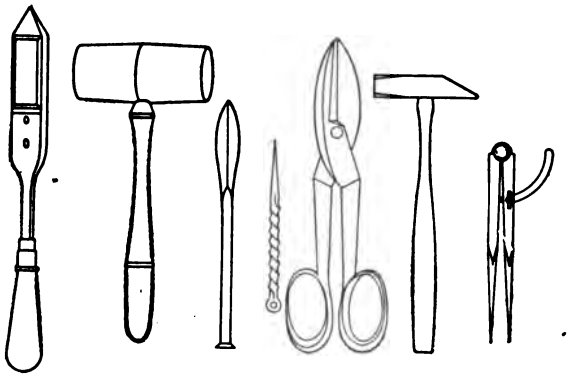


Fig. 195.

rious intersecting roofs, forming hips and valleys, render it necessary to give a short chapter on roof measurement. In Figs. 196 to 198 inclusive are shown respectively the plans with full size measurements for a flat, irregular, and intersected hipped roof, showing how the length of the hips and valleys are obtained direct from the architects' scale drawings.

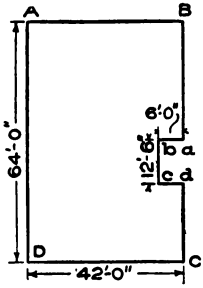


Fig. 196.

The illustrations shown herewith are not drawn to a scale as architects' drawings will be, but the measurements on the diagrams are assumed, which will clearly show the principles which must be applied when figuring from scale drawings. Assuming that the plans from which we are figuring are drawn to a quarter-inch scale, then when measurements are taken, every quarter inch represents one foot. $\frac{1}{8}$ inch = 6 inches, $\frac{1}{16}$ inch = 3 inches, etc. If the drawings were drawn to a half-inch scale, then $\frac{1}{2}$ inch = 12 inches, $\frac{1}{4}$ inch = 6 inches, $\frac{1}{8}$ inch = 3 inches, $\frac{1}{16}$ inch = $1\frac{1}{2}$ inches, etc.

A B C D in Fig. 196 represents a flat roof with a shaft at one side as shown by *a b c d*. In a roof of this kind we will figure it as if there was no air shaft at all. Thus 64 feet × 42 feet = 2,688 square feet. The shaft is 12.5 × 6 feet = 75 square feet; then 2,688 feet − 75 feet =

2,613 square feet of roofing, to which must be added an allowance for the flashing turning up against and into the walls at the sides.

In Fig. 197 is shown a flat roof with a shaft at each side, one shaft being irregular, forming an irregular shaped roof. The rule for obtaining the area is similar to that used for Fig. 196 with the exception that the area of the irregular shaft *x x x x* in Fig. 197 is determined differently to that of the shaft *b c d e*. Thus A B C D = 108 feet × 45 feet = 4,860 square feet. Find the area of *b c d e* which is 9.25 × 39.5 = 365.375 or 365⅜ square feet. To find the area of the irregular shaft, bisect *xx* and *xx* and obtain *a a*, measure the length of *a a* which is 48 feet, and multiply by 9. Thus 48 × 9 = 412, and 412 + 365.375 = 777.375. The entire roof minus the shafts = 4,860 square feet − 777.375 = 4,082.625 square feet of surface in Fig. 197.

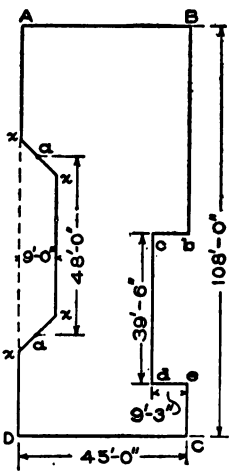


Fig. 197.

In Fig. 198 is shown the plan, front, and side elevations of an intersected hipped roof. A B C D represents the plan of the main building intersected by the wing E F G H. We will first figure the main roof as if there were no wing attached and then deduct the space taken

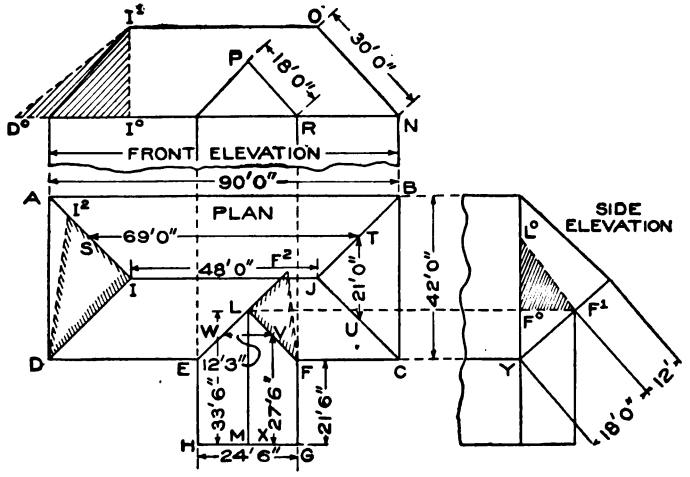


Fig. 198.

up by the intersection of the wing. While it may appear difficult to some to figure the quantities in a hipped roof, it is very simple, if the rule is understood. As the pitch of the roof is equal on four sides the length of the rafter shown from O to N in front elevation represents the true length of the pitch on each side. The length of the building at the eave is 90 feet and the length of the ridge 48 feet. Take $90 - 48 = 42$, and $42 \div 2 = 21$. Now either add 21 to the length of the edge or deduct 21 from the length of the eave, which gives 69 feet as shown from S to T. The length of the eave at the end is 42 feet and it runs to an apex at J. Then take 42 feet $\div$ 2 = 21, as shown from T to U. If desired the hip lines A I, J B and J C can be bisected, obtaining respectively the points S, T, and U, which when measured will be of similar sizes; 69 feet and 21 feet. As the length of the rafter O N is 30 feet, then multiply as follows: $69 \times 30 = 2070$. $21 \times 30 = 630$. Then $630 + 2{,}070 = 2{,}700$, and multiplying by 2 (for opposite sides) gives 5,400 square feet or 54 squares of roofing for the main building. From this amount deduct the intersection E L F in the plan as follows:

The width of the wing is 24 feet 6 inches and it intersects the main roof as shown at E L F. Bisect E L and L F and obtain points W and V, which when measured will be 12 feet 3 inches or one half of HG, 24 feet 6 inches. The wing intersects the main roof from Y to F^1 in the side elevation, a distance of 18 feet. Then take $18 \times 12.25 = 220.5$. Deduct 220.5 from 5400 = 5,179.5. The wing measures 33 feet 6 inches at the ridge L M, and 21 feet 6 inches at the eave F G, thus making the distance from V to X = 27 feet 6 inches. The length of the rafter of the wing is shown in front elevation by P R, and is 18 feet. Then $18 \times 27.5 = 495$, and multiplying by 2 (for opposite side), gives 995 sq. ft. in the wing. We then have a roofing area of 5,179.5 square feet in the main roof and 995 square feet in the wing, making a total of 6,174.5 square feet in the plan shown in Fig. 198.

If it is desired to know the quantity of ridge, hips, and valleys in the roof, the following method is used. The ridge can be taken from the plans by adding $48' + 33'6'' = 81' - 6''$. For the true length of the hip I D in the plan, drop a vertical line from I^1 in the front elevation until it intersects the eave line 1°. On the eave line extended, place the distance I D in the plan as shown from 1° to D° and draw a line from D° to I^1 which will be the true length of the hip I D in the plan. Multiply this length by 4, which will give the amount of ridge capping re-

quired. This length of hip can also be obtained from the plan by taking the vertical height of the roof I° I' in the elevation and placing it at right angles to I D in the plan, as shown, from I to I^{2}, and draw a line from I^{2} to D which is the desired length.

For the length of the valley L F in the plan, drop a vertical line from F^{1} in the side elevation until it intersects the eave line at F°. Take the distance F L in the plan and place it as shown from F° to L°, and draw a line from L° to F^{1}, which is the true length of the valley shown by L F in the plan. Multiply this length by 2, which will give the required number of feet of valley required. This length of valley can also be obtained from the plan by taking the vertical height of the roof of the wing, shown by F° F^{1} in the side elevation, and placing it at right angles to F L in the plan, from L to F^{2}, and draw a line from F^{2} to F which is the desired length similar to F^{1} L° in the side elevation.

FLAT-SEAM ROOFING

The first step necessary in preparing the plates for flat seam roofing is to notch or cut off the four corners of the plate as shown in Fig. 199 which shows the plate as it is taken from the box, the shaded corners *a a a a* representing the corners which are notched on the notching machine or with the shears. Care must be taken when cutting off these corners not to cut off too little otherwise the sheets will not edge well, and not to cut off too much, otherwise a hole will show at the corners when the sheets are laid. To find the correct amount to be cut off proceed as follows:

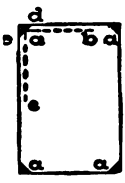


Fig. 199.

Assuming that a $\frac{1}{2}$-inch edge is desired, set the dividers at $\frac{1}{2}$ inch and scribe the lines *b a* and *a c* on the sheet shown in Fig. 199, and, where the lines intersect at *a*, draw the line *d e* at an angle of 45 degrees, which represents the true amount and true angle to be cut off on each corner. After all the sheets have been notched, they are edged as shown in Fig. 200, the long sides of the sheet being bent right and left, as shown at *a*, while the short side is bent as shown at *b*, making the notched corner appear as at *e*. In some cases after the sheets are edged the contract requires that the sheets be painted on the underside before laying. This is usually done with a small brush, being careful that the edges of the sheets

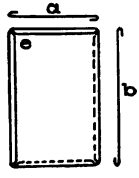


Fig. 200.

are not soiled with paint, which would interfere with soldering. Before laying the sheets the roof boards are sometimes covered with an oil or rosin-sized paper to prevent the moisture or fumes from below from rusting the tin on the underside. As before mentioned, the same method used for laying tin roofing would be applicable for laying copper roofing, with the exception that the copper sheets would have to be tinned about 1½ inches around the edges of the sheets after they are notched, and before they are edged.

In Fig. 201 is shown how a tin roof is started and the sheets laid when a gutter is used at the eaves with a fire wall at the side. A repre-

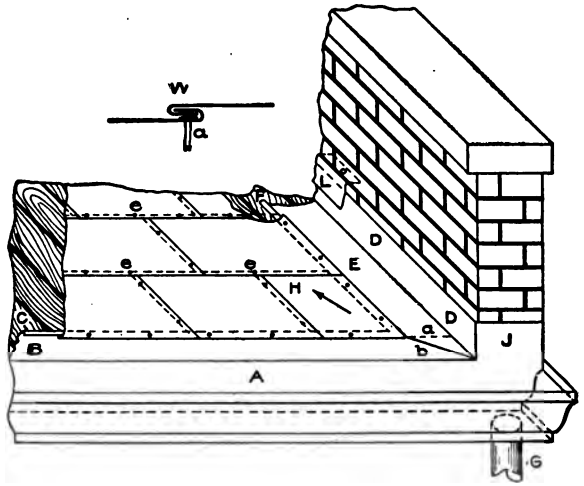


Fig. 201.

sents a galvanized iron gutter with a portion of it lapping on the roof, with a lock at C. In hanging the gutter it is flashed against the fire wall at J; after which the base flashing D D is put in position, flashing out on the roof at E, with a lock at F. Where the base flashing E miters with the flange of the gutter B it is joined as shown at *b*, allowing the flange E of the base flashing as shown by the dotted line *a*. As the water discharges at G, the sheets are laid in the direction of the arrow H, placing the nails at least 6 inches apart, always starting to nail at the butt *e e*, etc. Care should be taken when nailing that the nail heads are well covered by the edges, as shown in W, by *a*. Over the base flashing D D J the cap flashing L is placed, allowing it to go into the wall as at O.

When putting in base flashings there are two methods employed. In Fig. 202 is shown a side flashing between the roof and parapet wall. A shows the flashing turning out on the roof at B, with a lock C, attached and flashed into the wall four courses of brick above the roof line, as shown at D, where wall hooks and paintskins or roofer's cement are used to make a tight joint. Flashings of this kind should always be painted on the underside, and paper should be placed between the brick work and metal, because the moisture in the wall is apt to rust the tin. This method of putting in flashing is not advisable in new work, because when the building is new, the walls and beams are liable to settle and when this occurs the flange D tears out of the wall, and the result is disagreeable leaks that stain the walls. When a new roof is to be placed on an old building where the walls and copings are in place and the brick work and beams have settled, there is not so much danger of leakage.

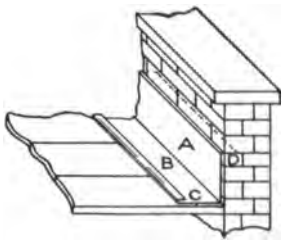


Fig. 202.

The proper method of putting in flashings and one which allows for the expansion and contraction of the metal and the settlement of the building is shown in Fig. 203, in which A shows the cap flashings,

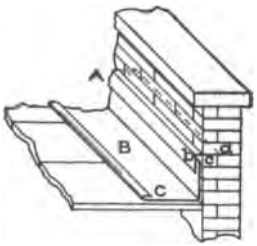


Fig. 203.

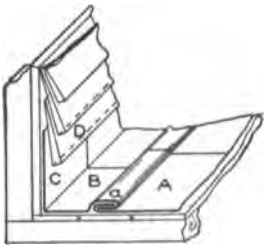


Fig. 204.

painted with two coats of paint before using. When the mason has built his wall up to four courses of brick above the roof line the cap flashing A is placed in position and the wall and coping finished; the base flashing B is then slipped under the cap A. In practice the cap flashing is cut 7 inches, then bent at right angles through the center, making each side *a* and *b* 3½ inches. The base flashing B is then slipped under the cap flashing A as shown at C.

Where the cost is not considered and a good job is desired, it is better to use sheet lead cap flashings in place of tin. They last longer, do not rust, and can be dressed down well to lay tight onto the base flashings. Into the lock C the sheets are attached. After the sheets are laid the seams are flattened down well by means of a heavy mallet, with slightly convex faces, after which the roof is ready for soldering. When a base flashing is required on a roof which abuts against a wall composed of clap boards or shingles as shown in Fig. 204, then, after the last course of tin A has been laid, the flashing B with the lock *a* is locked into the course A and extends the required distance under the boards D. The flashing should always be painted and allowed to dry before it is placed in position. In the previous figures it was shown how the sheets are edged, both sides being edged right and left. In Fig. 205 is shown what is known as a valley sheet, where the short sides are edged both one way, as shown at *a a*, and the long sides right and left as shown at *b b*. Sheets of this kind are used when the water runs together from two directions as shown by A in Fig. 206. By having the locks *a* and *a* turned one way the roof is laid in both directions.

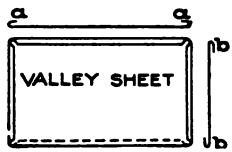


Fig. 205.

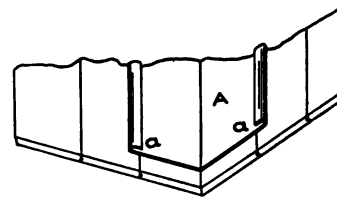


Fig. 206.

Fig. 207 shows a part plan of a roof and chimney A, around which the flashing B C D E is to be placed, and explains how the corners C and D are double seamed, whether on a chimney, bulkhead, or any other object on a roof when the water flows in the direction of the arrow F. The first operation is shown at *a* and the final operation at *b*. Thus it will be seen that the water flows past the seam and not against it. In laying flat seam roofing especially when copper is used, allowance must be made for the expansion and contraction of the sheets.

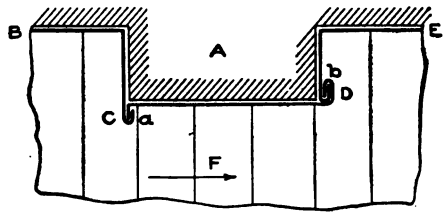


Fig. 207.

Care should be taken not to nail directly through the sheet as is shown in W, Fig. 201. While this method is generally employed in tin roofing, on a good job, as well as on copper roofing, cleats as shown at D in Fig. 208 should be used.

To show how they are used, A and B represent two locked-edged sheets. The lock on the cleat D is locked into the edge of the sheets and nailed into the roof boards at *a b c* and *d*, ar as often as required.

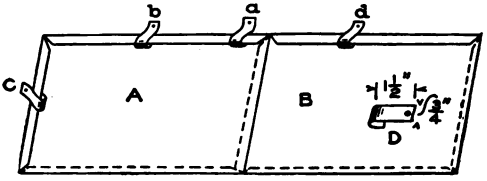


Fig. 208.

In this manner the entire roof can be fastened with cleats without having a nail driven into the sheets, thereby allowing for expansion and contraction of the metal. The closer these cleats are placed, the firmer the roof will be and the better the seams will hold. By using fewer cleats, time may be saved in laying the roof, but double this time is lost when soldering the seams, for the heat of the soldering copper

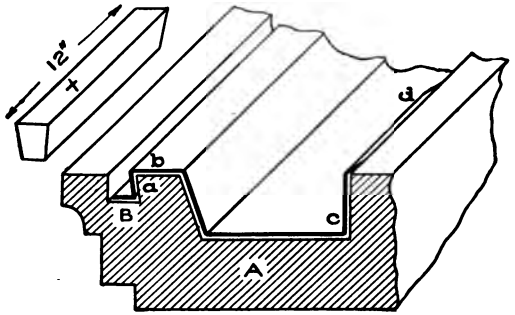


Fig. 209.

will raise the seams, causing a succession of buckles, which retard soldering and require 10 per cent more solder. When the seams are nailed or cleated close it lays flat and smooth and the soldering is done with ease and less solder.

When a connection is to be made between metal and stone or terra cotta, the method shown in Fig. 209 is employed. This illustration shows a stone or terra-cotta cornice A. The heavy line *a b c d*

represents the gutter lining, which is usually made from 20-oz. cold-rolled copper. If the cornice A is of stone, the stone cutter cuts a raggle into the top of the cornice A as at B, dove-tail in shape, after which the lining *a b c d* is put in position as shown. Then, being careful that there is no water or moisture in the raggle B, molten lead is poured into the raggle and after it is cooled it is dressed down well with the caulking chisel and hammer.

By having the dove-tail cut, the lead is secured firmly in position, holding down the edge of the lining and making a tight joint. Should the cornice be of terra cotta this raggle is cut into the clay before it is baked in the ovens. This method of making connection between

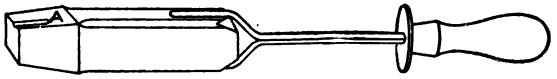


Fig. 210.

metal and stone is the same no matter whether a gutter or upright wall is to be flashed. When a flashing between a stone wall and roof is to be made tight, then instead of using molten lead, cakes of lead are cast in molds made for this purpose, about 12 inches long, and these are driven into the raggle B as shown in Fig. 209 at X.

The most important step in roofing is the soldering. The style of soldering copper employed is shown in Fig. 210 and weighs at least 8 pounds to the pair. When rosin is used as a flux, it is also employed in tinning the coppers, but when acid is used as a flux for soldering zinc or galvanized iron, salammoniac is used for tinning the coppers. It will be noticed that the soldering coppers are forged square at the ends, and have a groove filed in one side as shown at A. When the copper is turned upward the groove should be filed toward the lower side within $\frac{1}{4}$ inch from the corner, so that when the groove is placed upon the seam, as shown in Fig. 211, it acts as a guide to the copper as the latter is drawn along the seam. The groove *a* being in the position shown, the largest heated surface *b* rests directly on the seam, "soaking" it thoroughly with solder. As the heat draws the solder between the locks, about 6 pounds of $\frac{1}{2}$ and $\frac{1}{2}$ solder are required for 100 square feet of surface using 14 x 20-inch tin. The use of acid in soldering seams in a tin roof is to be avoided as acid coming in contact with the

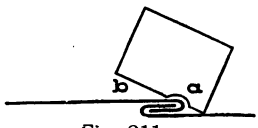


Fig. 211.

bare edges and corners, where the sheets are folded and seamed together, will cause rusting. No other soldering flux but good clean rosin should be employed. The same flux (rosin) should be used when soldering copper roofing whose edges have previously been tinned with rosin.

We will now consider the soldering of upright seams. The soldering copper to be employed for this purpose is shaped as shown in Fig. 212. It is forged to a wedge shape, about 1 inch wide and ¼ inch

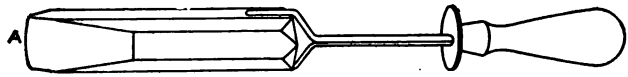


Fig. 212.

thick at the end, and is tinned on one side and the end only; if tinned otherwise, the solder, instead of remaining on the tinned side when soldering, would flow downward; by having the soldering copper tinned on one side only, the remaining sides are black and do not tend to draw the solder downward. The soldering copper being thus prepared, the upright seam, shown in Fig. 213, where the sheet B overlaps the sheet A 1″, is soldered by first tacking the seam to make it lay close, then thoroughly soaking the seam, and then placing ridges of solder across it to strengthen the same. In using the soldering copper it should be held in the position shown by C, which allows the solder to flow forward and into the seam, while if the copper were held as shown by D, the solder would flow backward and away from the seam. In "soaking" the seam with solder the copper should be placed directly over the lapped part, so that the metal gets thoroughly heated and draws the solder between the joint. It makes no difference where this cross joint occurs; the same methods are used.

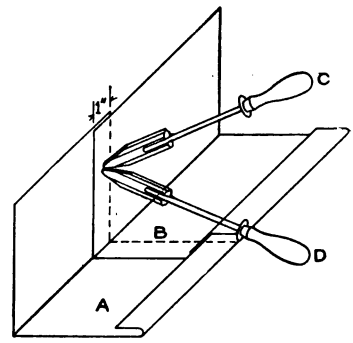


Fig. 213.

The roof being completed, the rosin is scraped off the seams and the roof cleaned and painted with good iron oxide and linseed oil paint. Some roofers omit the scraping of rosin and paint directly over it. This is the cause of rusting of seams which sometimes occurs. If the

paint is applied to the rosin, the latter, with time, will crack, and the rain will soak under the cracked rosin to the tin surface. Even when the surface of the roof is dry, by raising the cracked rosin, moisture will often be found underneath, which naturally tends to rust the plate more and more with each storm. If the rosin is removed, the entire tin surface is protected by paint.

One of the most difficult jobs in flat-seams roofing is that of covering a conical tower. As the roof in question is round in plan and tapering in elevation, it is necessary to know the method of cutting the various patterns for the sheets. In Fig. 214 A B C shows the elevation of a tower to be covered with flat seam roofing, using 10 × 14-inch tin at the base. Assuming that the tower through B C is 10 feet 6 inches, or 126 inches, in diameter, the circumference is obtained by multiplying 126 by 3.1416 which equals 395.8416, or say 396 inches. As 10 x 14-inch plate is to be used at the base of the tower the nearest width which can be employed, and which will divide the space into equal spaces, is $13\frac{1}{8}$ inches without edges, thus dividing the circumference in 30 equal spaces. This width of $13\frac{1}{8}$ inches together with the length of the rafter A B or B C in elevation, will be the basis from which all the patterns for the various courses will be laid off.

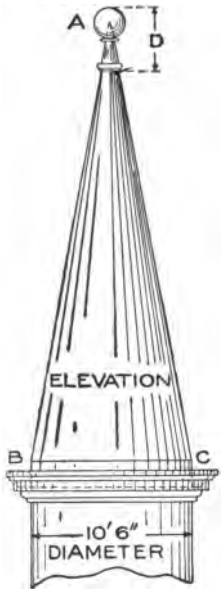


Fig. 214.

At any convenient place in the shop or at the building, stretch a piece of tar felting of the required length, tacking it at the four corners with nails to keep the paper from moving. Upon the center of the felting strike a chalk line as A B in Fig. 215, making it equal to the length of the rafter A B or A C in Fig. 214. At right angles to A B in Fig. 215 at either side, draw the lines B D and B C each equal to $6\frac{3}{8}$ inches, being one half of the $13\frac{1}{8}$ above referred to. From the points C and D draw lines to the apex A (shown broken). As the width of the sheet used is 10 inches and as we assume an edge of $\frac{3}{8}$ inch for each side, thus leaving $9\frac{1}{4}$ inches, measure on the vertical line A B lengths of $9\frac{1}{4}$ inches in succession, until the apex A is reached, leaving

the last sheet at the top to come as it may. Through the points thus obtained on A B draw lines parallel to C D intersecting the lines A C and A D as shown. Then the various shapes marked 1 2 3 etc. will be the net patterns for similarly numbered courses. Take the shears and cut out the patterns on the felting and number them as required.

For example, take the paper pattern No. 1, place it on a sheet of tin as shown in Fig. 216, and allow ⅜-inch edges all around, and notch the corners A B C and D. Mark on the tin pattern "No. 1, 29 more", as 30 sheets are required to go around the tower, and cut 29 more for course No. 1. Treat all of the paper patterns from No. 1 to the apex in similar manner. Of course where the patterns become smaller in size at the top, the waste from other patterns can be used.

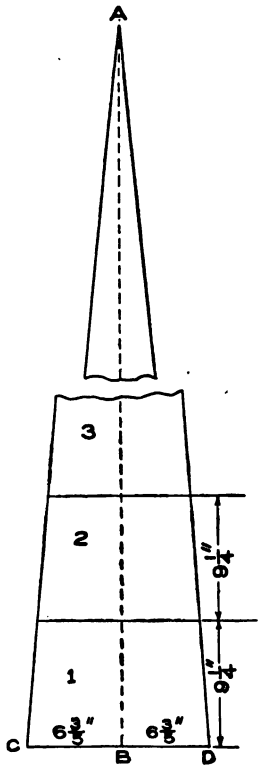


Fig. 215.

In Fig. 217 is shown how the sheets should be edged, always being careful to have the narrow side towards the top with the edge toward the outside, the same as in flat seam roofing. Lay the sheets in the usual manner, breaking joints as in general practice. As the seams are not soldered care must be taken to lock the edges well. After the entire roof is laid and before closing the seams with the mallet take a small brush and paint the locks with thick white lead, then close with the mallet. This will make a water-tight job. After the roof is completed the finial D in Fig. 214 is put in position.

Fig. 216.

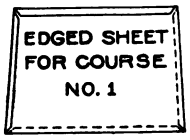


Fig. 217.

As the method used for obtaining the patterns for the various sheets in Fig. 215 is based upon the principle used in obtaining the envelope of a right cone, some student may say that in accurate pat-

terns the line from C to D and all following lines should be curved, as if struck with a radius from the center A, and not straight as shown. To those the writer would say that the curve would be so little on a small pattern, where the radius is so long, that a straight line answers the purpose just as well in all practical work; for it would amount to considerable labor to turn edges on the curved cut of the sheet, and there is certainly no necessity for it.

When different metals are to be connected together, as for instance tin roofing to copper flashing, or copper tubes to galvanized iron gutters, or zinc flashings in connection with copper linings, care must be taken to have the copper sheets thoroughly tinned on both sides where it joins to the galvanized iron, zinc, or other metal, to avoid any electrolysis between the two metals. It is a fact not well known to roofers that if we take a glass jar and fill it with water and place it in separately, two clean strips, one of zinc and the other of copper, and connect the two with a thin copper wire, an electrical action is the result, and if the connection remains for a long time (as the action is very faint) the zinc would be destroyed, because, it may be said, the zinc furnishes the fuel for the electrical action, the same as wood furnishes the fuel for the fire. Therefore, if the copper was not tinned, before locking into the other metal, and the joint became wet with rain, the coating of the metal would be destroyed by the electrical action between the two metals, and the iron would rust through.

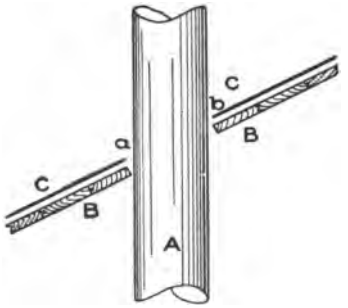


Fig. 218.

While the roofer is seldom called upon to lay out patterns for any roofing work occasion may arise that a roof flashing is required around a pipe passing through a roof of any pitch, as shown in Fig. 218, in which A represents a smoke or vent pipe passing through the roof B B, the metal roof flashing being indicated by C C. If the roof B B were level the opening to be cut into the flashing C C would simply be a true circle the same diameter as the pipe A. But where the roof pitches the opening in the flashing becomes an ellipse, whose minor axis is the same as the diameter of the pipe, and whose major axis is

equal to the pitch *a b*. In Fig. 219 is shown how this opening is obtained by the use of a few nails, a string, and a pencil, which the roofer will always have handy.

First draw the line A B representing the slant of the roof, and then make the pipe of the desired size passing through this line at its proper angle to the roof line. Next draw the center line R S of the pipe, as shown. Call the point where this line intersects the roof line, I, and the points where D E and C F intersect A B, G and H respectively. Through I draw K L at right angles to A B, making K I and I L each equal to the half diameter of the pipe. Having established the minor axis K L and the major axis G H, the ellipse is made by taking I H, or half the major axis, as a radius, and with L as a center strike arcs intersecting the major axis, at points M and N. Drive a small nail in each of these two points and attach a string to the nails as shown by the dotted lines K M N, in such a way that when a pencil point is placed in the string it will reach K. Move the pencil along the string, keeping it taut all the time until the ellipse K H L G is obtained. Note how the position of the string changes when it reaches *a*, then *b*, etc.

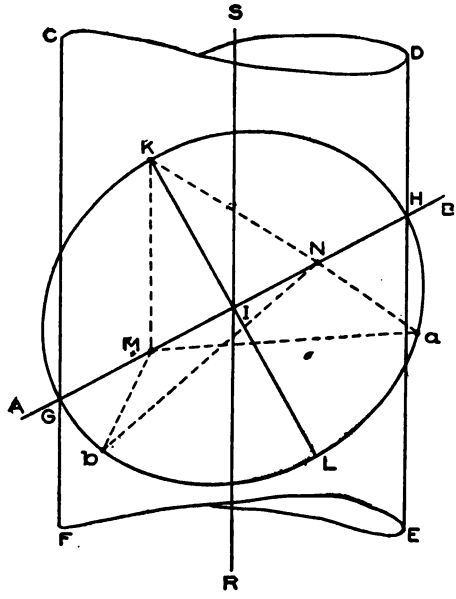


Fig. 219.

STANDING-SEAM ROOFING

Another form of metal roofing is that known as standing seam, which is used on steep roofs not less than $\frac{1}{4}$ pitch, or $\frac{1}{8}$ the width of the building. It consists of metal sheets whose cross or horizontal seams are locked as in flat seam roofing, and whose vertical seams are standing locked seams, as will be described in connection with Figs.

220 to 229 inclusive. Assume that 14 x 20-inch sheets are used and the sheets are edged on the 20-inch sides only, as shown by A in Fig. 220, making the sheet 13 x 20 inches. After the required number of sheets have been edged, and assuming that the length of the pitched roof is 30 feet, then as many sheets are locked together as will be required, and the seams are closed with the mallet and soldered. In practice these strips are prepared of the required length in the shop, painted on the underside, and when dry are rolled up and sent to the building. If desired they can be laid out at the building, which avoids the buckling caused by rolling and transportation from the shop to the job.

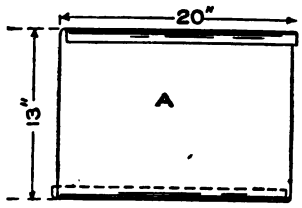


Fig. 220.

After the necessary strips have been prepared they are bent up with the roofing tongs, or, what is better and quicker, the roofing edger for standing-seam roofing. This is a machine into which the strips of tin are fed, being discharged in the required bent form shown at A or B in Fig. 221, bent up 1 inch on one side and 1¼ inches on the other side. Or the machine will, if desired, bend up 1¼ inches and 1½ inches, giving a ¾-inch finished doubled seam in the first case and a 1-inch seam in the second. When laying standing-seam roofing, in no case should any nails be driven into the sheets. This applies to tin, copper or galvanized iron sheets. A cleat should be used, as shown in Fig. 222, which also shows the full size for laying the sheets given in Fig. 221. Thus it will be seen in Fig. 222 that ¼ inch has been added over the measurements in Fig. 221, thus allowing edges.

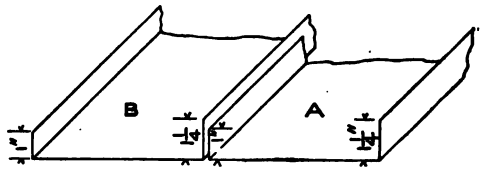


Fig. 221.

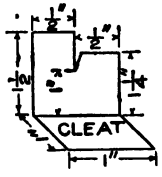


Fig. 222.

These cleats shown in Fig. 222 are made from scrap metal; they allow for the expansion and contraction of the roofing and are used in practice as shown in Fig. 223, which represents the first operation in laying a standing-seam roof, and in which A represents the gutter with a lock attached at B. The

gutter being fastened in position by means of cleats under the lock B—the same as in flat seam roofing—the standing seam strips are laid as follows: Take the strip C and lock it well into the lock B of the gutter A as shown, and place the cleat shown in Fig. 222 tightly against the upright bend of the strip C in Fig. 223 as shown at D, and fasten it to the roof by means of a 1-inch roofing nail *a*.

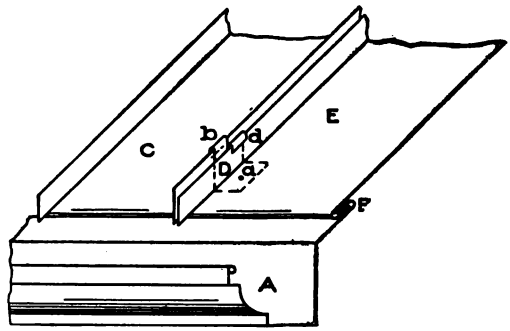


Fig. 223.

Press the strip C firmly onto the roof and turn over edge *b* of the cleat D. This holds the sheet C in position. Now take the next sheet E, press it down and against the cleat D and turn over the edge *d*, which holds E in position. These cleats should be placed about 18 inches

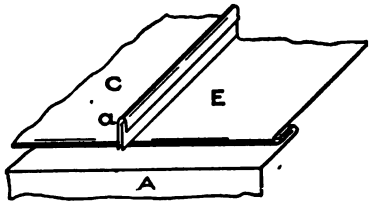


Fig. 224.

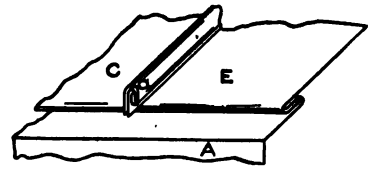


Fig. 225.

apart and by using them it will be seen that no nails have been driven through the sheets, the entire roof being held in position by means of the cleats only.

The second operation is shown in Fig. 224. By means of the hand double seamer and mallet or with the roofing double seamers and squeezing tongs, the single seam is made as shown at *a*. The third and last operation is shown in Fig. 225 where by the use of the same tools the doubled seam *a* is obtained. In Fig. 226 is shown how the finish is made with a comb ridge at the top. The sheets A A A have

on the one side the single edge as shown, while the opposite side B has a double edge turned over as shown at *a*. Then, standing seams *b b b* are soldered down to *e*.

In Fig. 227 is shown how the side of a wall is flashed and counter

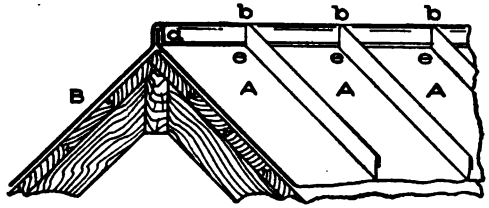


Fig. 226.

flashed. A shows the gutter, B the leader or rain water conductor, and C the lock on the gutter A, fastened to the roof boards by cleats

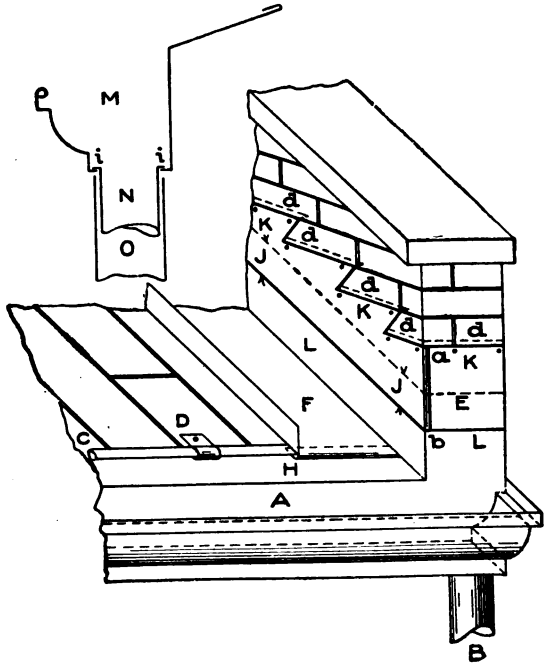


Fig. 227.

as shown at D. The back of the gutter is flashed up against the wall as high as shown by the dotted line E. F represents a standing-seam strip locked into the gutter at H and flashed up against the wall as high

as shown by the dotted line J J. As the flashing J J E is not fastened at any part to the wall the beams or wall can settle without disturbing the flashing. The counter or cap flashing K K K is now stepped as shown by the heavy lines, the joints of the brick work being cut out to allow a one-inch flange *d d d* etc. to enter. This is well fastened with flashing hooks, as indicated by the small dots, and then made water-tight with roofer's cement. As will be seen the cap flashing overlaps the base flashing a distance indicated by J J and covers to L L; the corner is double seamed at *a b*. M shows a sectional view through the gutter showing how the tubes and leaders are joined. The tube N is flanged out as shown at *i i*, and soldered to the gutter; the leader O is then slipped over the tube N as shown, and fastened.

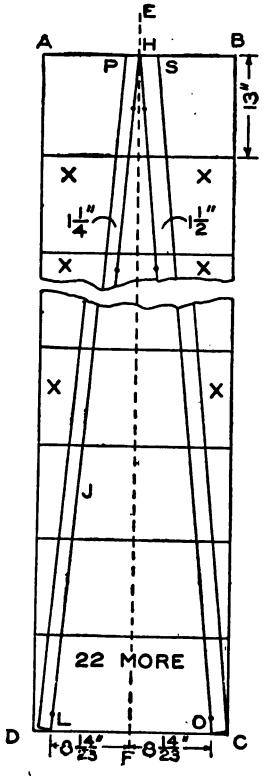


Fig. 228.

In the section on Flat-Seam Roofing it was explained how a conical tower, Fig. 214, would be covered. It will be shown now how this tower would be covered with standing-seam roofing. As the circumference of the tower at the base is 396 inches, and assuming that 14 x 20-inch tin plate is to be used at the base of the tower, the nearest width which can be employed and which will divide the base into equal spaces is $17\frac{5}{23}$ inches, without edges, thus dividing the circumference into 23 equal parts. Then the width of $17\frac{5}{23}$ inches and the length of the rafter A B or A C in elevation will be the basis from which to construct the pattern for the standing seam strip, for which proceed as follows:

Let A B C D in Fig. 228 represent a 20-inch wide strip locked and soldered to the required length. Through the center of the strip draw the line E F. Now measure the length of the rafter A B or A C in Fig. 214 and place it on the line E F in Fig. 228 as shown from H to F. At right angles to H F on either side draw F O and F L making each equal to $8\frac{14}{23}$ inches, being one half of the $17\frac{5}{23}$ above referred to.

From points L and O draw lines to the apex H (shown broken). At right angles to H L and H O draw lines H P equal to 1¼ inches and H S equal to 1½ inches respectively. In similar manner draw L D and O C and connect by lines the points P D and S C. Then will P S C D be the pattern for the standing seam strip, of which 22 more will be required. When the strips are all cut out, use the roofing tongs and bend up the sides, after which they are laid on the tower, fastened with cleats, and double seamed with the hand seamer and mallet in the usual manner.

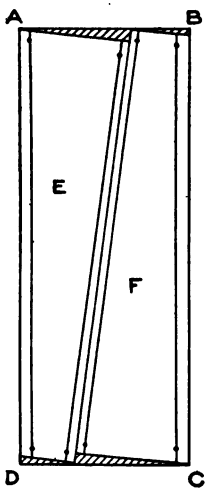


Fig. 229.

If the tower was done in copper or galvanized sheet iron or steel, where 8-foot sheets could be used, as many sheets would be cross-locked together as required; then metal could be saved, and waste avoided, by cutting the sheets as shown in Fig. 229 in which A B C D shows the sheets of metal locked together, and E and F the pattern sheets, the only waste being that shown by the shaded portion. Where the finial D in Fig. 214 sets over the tower, the standing seams are turned over flat as much as is required to receive the finial, or small notches would be cut into the base of the finial, to allow it to slip over the standing seams. Before closing the seams, they are painted with white lead with a tool brush, then closed up tight, which makes a good tight job.

CORRUGATED IRON ROOFING AND SIDING

Corrugated iron is used for roofs and sides of buildings. It is usually laid directly upon the purlins in roofs constructed as shown in Figs. 230 and 231, the former being constructed to receive sidings of corrugated iron, while in the latter figure the side walls of the building are brick. Special care must be taken that the projecting edges of the corrugated iron at the eaves and gable ends of the roof are well secured, otherwise the wind will loosen the sheets and fold them up. The corrugations are made of various sizes such as 5-inch, 2½-inch, 1¼-inch and ¾-inch, the measurements always being from A to B in Fig. 232, and the depth being shown by C. The smaller corrugations give a

more pleasing appearance, but the larger corrugations are stiffer and will span a greater distance, thereby permitting the purlins to be further apart.

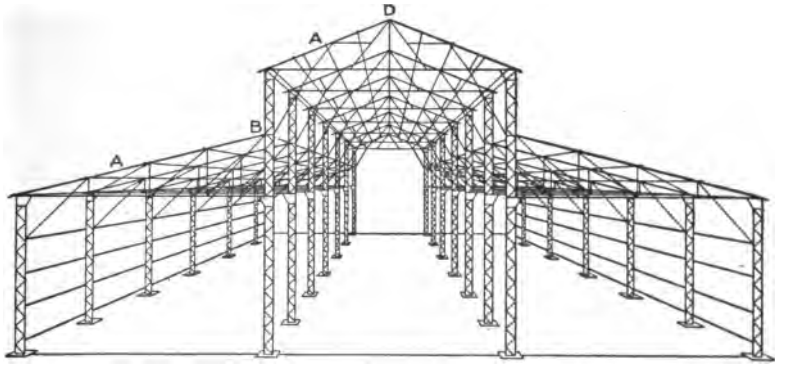


Fig. 230.

The thickness of the metal generally used for roofing and siding varies from No. 24 to No. 16 gauge. By actual trial made by The

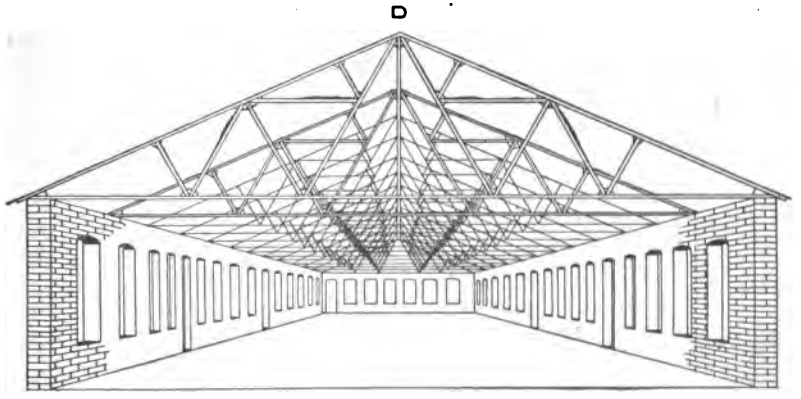


Fig. 231.

Keystone Bridge Company it was found that corrugated iron No. 20, spanning 6 feet, began to give permanent deflection at a load of 30 lb. per square foot, and that it collapsed with a load of 60 lb. per square foot. The distance between centers of purlins should, therefore, not exceed 6 feet, and preferably be less than this.

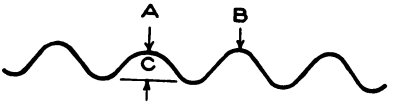


Fig. 232.

TABLES

The following tables will prove of value when desiring any information to which they appertain.

MEASUREMENTS OF CORRUGATED SHEETS

Dimensions of Sheets and Corrugations.

Kind of corrugation	Width of corrugation	Depth of corrugation	No. of corrugations to the sheet	Covering width after lapping one corrugation	Width of sheet after corrugated	Length of the longest sheets furnished
5 inch.	5 inch.	1 inch.	6	24 inch.	27 inch.	10 feet.
2½ inch.	2½ inch.	½ to ⅝ inch.	10	24 inch.	26 inch.	10 feet.
1¼ inch.	1¼ inch.	⅜ to ½ inch.	19½	24 inch.	26 inch.	10 feet.
¾ inch.	¾ inch.	¼ inch.	84½	25 inch.	26 inch.	8 feet.

RESULTS OF TEST

of a corrugated sheet No. 20, 2 feet wide, 6 feet long between supports, loaded uniformly with fire clay.

Load per square foot. lb.	Deflection at center under load. Inches.	Permanent Deflection, load removed.
5	$\frac{1}{4}$	0
10	$\frac{3}{4}$	0
15	1	0
20	$1\frac{1}{4}$	0
25	$1\frac{3}{8}$	0
30	$1\frac{7}{8}$	$\frac{1}{8}$
35	$2\frac{1}{2}$	$\frac{3}{8}$
40	$2\frac{5}{8}$	$\frac{1}{4}$
45	$3\frac{1}{2}$	$1\frac{1}{8}$
50	4	$1\frac{1}{2}$
55	$6\frac{1}{2}$	Not noted.
60	Broke down.	" "

The following table shows the distance apart the supports should be for different gauges of corrugated sheets:

Nos. 16 and 18.....6 to 7 feet apart.
Nos. 20 and 22 .....4 to 5 feet apart.
No. 24.....2 to 4 feet apart.
No. 28..... 2 feet apart.

The following table is calculated for sheets 30½ inches wide before corrugating.

No. by Birmingham gauge	Thickness Inch	Weight per square ft., flat Lb.	Weight per square ft., corrugated Lb.	Weight per square of 100 square feet, when laid, allowing 6 inches lap in length and 2½ inches or one corrugation in width of sheet, for sheet lengths of:						Weight per square ft., flat, galvanized Lb.
				5 feet	6 feet	7 feet	8 feet	9 feet	10 feet	
16	.065	2.61	3.28	365	358	353	350	348	346	2.95
18	.049	1.97	2.48	275	270	267	264	262	261	2.31
20	.035	1.40	1.76	196	192	190	188	186	185	1.74
22	.028	1.12	1.41	156	154	152	150	149	148	1.46
24	.022	.88	1.11	123	121	119	118	117	117	1.22
26	.018	.72	.91	101	99	97	97	96	95	1.06

LAYING CORRUGATED ROOFING

When laying corrugated iron on wood sheathing use galvanized iron nails and lead washers. The advantage in using lead washers is that they make a tight joint and prevent leaking and rusting at the nail hole; the washer being soft it easily shapes itself to any curve. In Fig. 233 is shown how these washers are used; A shows the full size nail

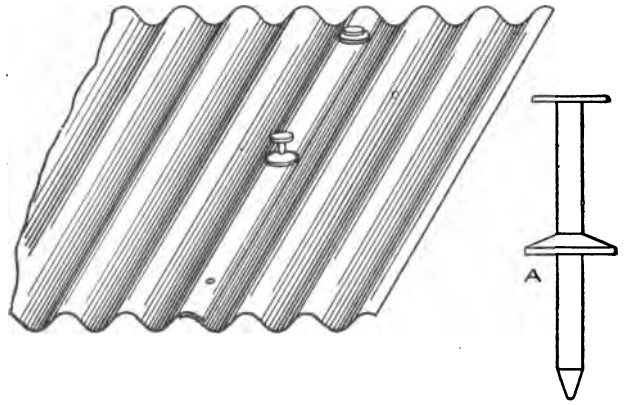


Fig. 233.

and washer. When laying, commence at the left hand corner of the eave and end of the building. Continue laying to the ridge by lapping the second sheet over the first 4 inches, the left-hand edge being finished by means of a gable band A, formed as shown in Fig. 234, into which the corrugated sheet B is well bedded in roofer's cement C. When it is not desired to use this gable band the sheet must be well secured at the edge to keep the wind from raising the sheets from the roof in a storm, as at A in Fig. 230.

Should the gable have a fire wall, then let the sheets A butt against the wall and flash with corrugated flashing as shown in Fig. 235, over which the regular cap or counter flashing is placed as explained in connection with Fig. 227. Should the ridge of the roof A butt against a wall, as shown at B in Fig. 230, then an end-wall flashing is used as is shown in Fig. 236 which must also be capped, by either using cap flashing or allowing the corrugated siding to overlap this end-wall flashing

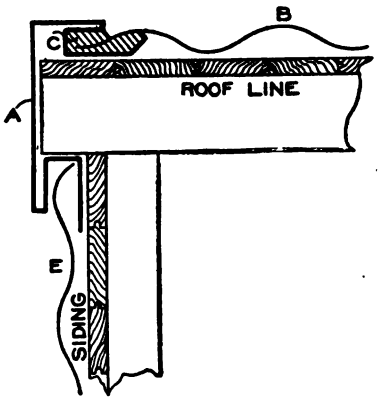


Fig. 234.

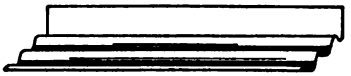


Fig. 235.

as would be the case at B in Fig. 230. Now commence the second course at the eaves, giving one and one half corrugations for side lap, being careful that the side corrugations center each other exactly and nail with washers as shown in Fig. 237. Nail at every other corrugation at end laps, and at about every 6 inches at side laps, nailing through top of corrugation as shown in Fig. 237. Continue laying in this manner until the roof is covered.

Fig. 236.

The same rule is to be observed in regard to laps and flashing if the corrugated iron were to be fastened to iron purlins, and the method of fastening to the iron frames would be accomplished as shown in Figs. 238 to 240 inclusive. Assuming that steel structures are to be covered, as shown in Figs. 230 and 231, then let A in Fig. 238 be the iron rafter, B the cross angles on which the sheets D are laid, then by means of the clip or clamp C, which is made from hoop iron and bent around the angle B, the sheets are riveted in position. In Fig. 239 is shown another form of clamp, which is bent over the bottom of the angle iron.

Fig. 237.

Fig. 240 shows still another method, where the clamp F is riveted to the sheet B at E, then turned around the angle A at D. To avoid having the storm drive in between the corrugated opening at the eaves, corrugated wood filler is used as shown in Fig. 241. This keeps out the

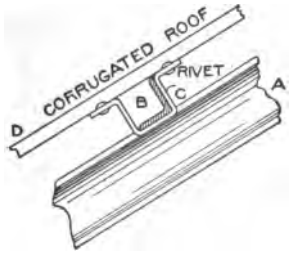


Fig. 238.

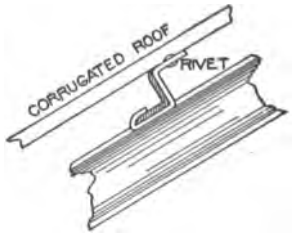


Fig. 239.

snow and sleet. On iron framing this is made of pressed metal. Another form of corrugated iron roofing is shown in Fig. 242. This is put down with cleats in a manner similar to standing-seam roofing.

If there are hips on the roof, the corrugated iron should be carefully cut and the hip covered with sheet lead. This is best done by having a wooden cove or filler placed on the hip, against which the roofing butts. Sheet lead is then formed over this wooden core and into the corrugations, and fastened by means of wood screws through the lead cap into the wooden core. The lead being soft, it can be worked into any desired shape. When a valley occurs in a hipped roof, form from plain sheet iron a valley as shown in Fig. 243, being sure to give it two coats of paint before laying, and make it from 24-inch wide sheets, bending up 12 inches on each side. Fit it in the valley, and cut the corrugated iron to fit the required angle. Then lap the corrugated iron over the valley from 6 to 8 inches.

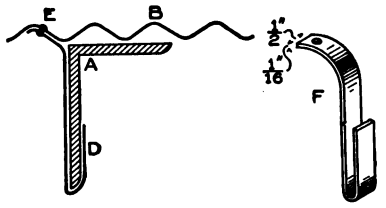


Fig. 240.

Fig. 241.

When a chimney is to be flashed, as shown in Fig. 244, use plain iron, bending up and flashing into the chimney joints, and allowing

the flashing to turn up under the corrugated iron at the top about 12 inches and over the corrugated iron at the bottom about the same distance. At the side the flashing should have the shape of the corrugated iron and receive a lap of about 8 inches, the entire flashing

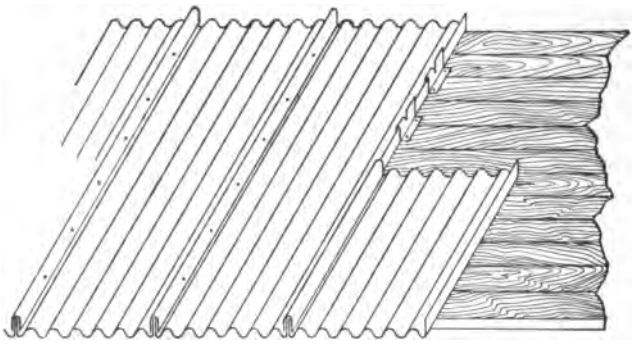


Fig. 242.

being well bedded in roofer's cement. When a water-tight joint is required around a smoke stack, as shown in Fig. 245, the corrugated iron is first cut out as shown, then a flashing built around one half the upper part of the stack to keep the water from entering inside. This is best done by using heavy sheet lead and riveting it to the sheets, using strips of similar corrugated iron as a washer to avoid damaging the lead. Before riveting, the flashing must be well bedded in roofer's cement and then make a beveled angle of cement to make a good joint. After this upright flashing is in position a collar is set over the same and fastened to the stack by means of an iron ring bolted and made tight as shown. Cement is used to make a water-tight joint around the stack. This construction gives room for the stack to sway and allows the heat to escape.

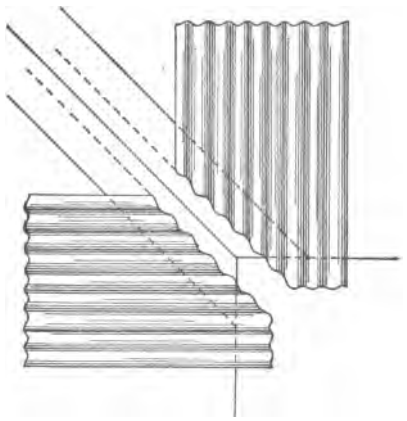


Fig. 243.

Sometimes the end-wall flashing shown in Fig. 236 can be used

to good advantage in building the upright flashing in Fig. 245. Where the corrugated iron meets at the ridge, as at D and D in Figs. 230 and

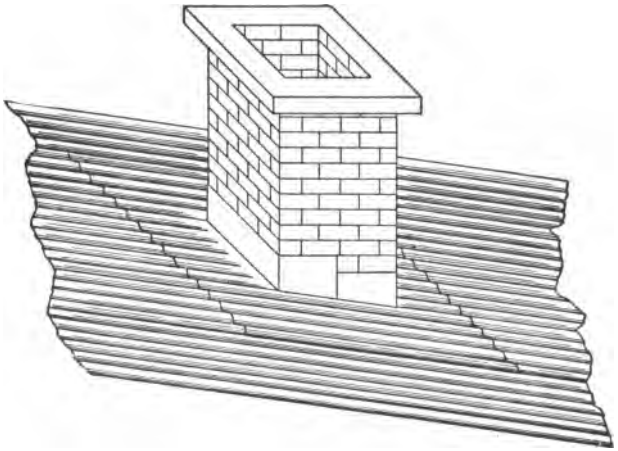


Fig. 244.

231, a wooden core is placed in position as explained in connection with the hip ridge, and an angle ridge, pressed by dealers who furnish the

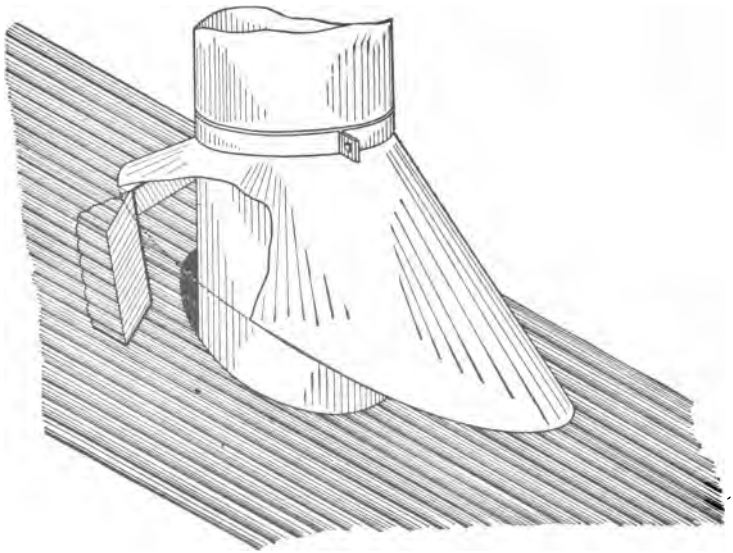


Fig. 245.

corrugated iron, is placed over the ridge as shown in Fig. 246. When a ridge roll is required, the shape shown in Fig. 247 is employed.

These ridges are fastened direct to the roof sheets by means of riveting or bolting.

LAYING CORRUGATED SIDING

Before putting on any corrugated siding or clapboarding, as shown in Fig. 248, a finish is usually made at the eaves by means of a

Fig. 246.

hanging gutter or a plain cornice, shown in Fig. 249, which is fastened to the projecting wooden or iron rafters. This method is generally used on elevators, mills, factories, barns, etc., where corrugated iron, crimped iron or clapboards are used for either roofing or siding. This

Fig. 247.

style of cornice covers the eaves and gable projections, so as to make the building entirely ironclad. When laying the siding commence at the left-hand corner, laying the courses from base to cornice, giving the sheets a lap of two inches as the ends and one and one half corruga-

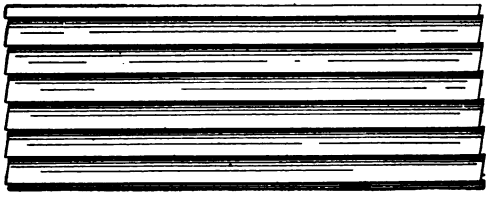


Fig. 248.

tions at the sides. Nail side laps every 6 inches and end laps at every other corrugation, driving the nails as shown in Fig. 250.

Where the sheets must be fastened to iron framing use the same method as explained in connection with Figs. 238, 239 and 240. In this case, instead of nailing the sheets, they would be riveted. If siding is put on the wooden studding care should be taken to space the studding the same distance apart as the laying width of the iron used. In

this case pieces of studding should be placed between the uprights at the end of each sheet to nail the laps. When covering grain elevators

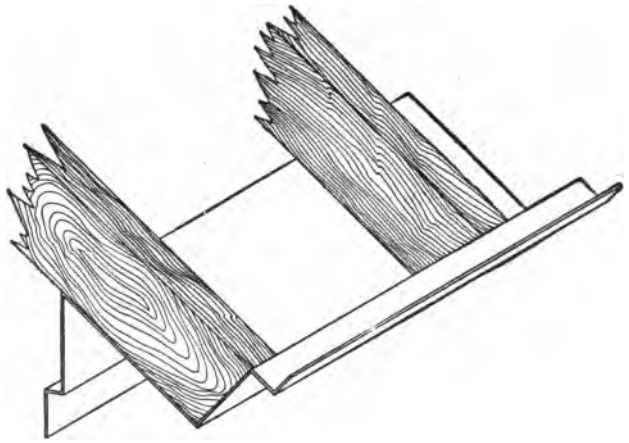


Fig. 249.

it is necessary to use swinging scaffolds. Commence at the base and carry up the course to the eave, the length of the scaffold. Commence at the left hand and give the sheets a lap of one corrugation on the side and a two-inch lap at the end. Nail or rivet in every corrugation 3 inches from the lower end of the sheet; this allows for settling of the building.

Fig. 250.

When any structure is to be covered on two or more sides, corner casings made of flat iron are employed, of a shape similar to that shown at B, Fig. 251. It will be seen that a rabbet is bent on both sides *a* and *b* to admit the siding. This makes a neat finish on the outside and hides the rough edges of the siding. If a window opening is to have casings a jamb is used as shown at A, Fig. 251, which has a similar rabbet at *a* to receive the siding, and a square bend at *b* to nail against the frame. In Fig. 252 is shown the cap of a window or opening. It is

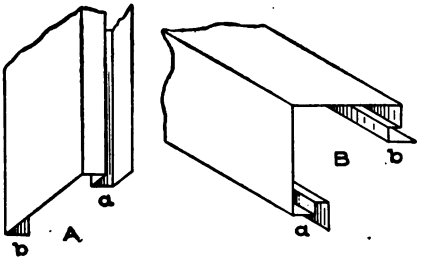


Fig. 251.

bent so that *a* is nailed to the window or other frame at the bottom, while *b* forms a flashing over which the siding will set. Fig. 253 shows the sill of a window, which has a rabbet at *a*, in which the siding is

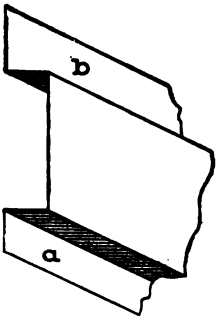


Fig. 252.

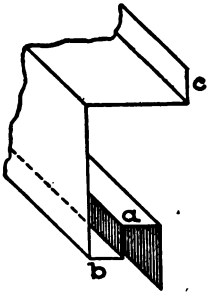


Fig. 253.

slipped; then *b* forms a drip, and any water coming over the sill passes over the siding without danger of leaks; *c* is nailed in white lead to the window frame.

Another use to which corrugated iron is put is to cover sheds and awnings. Sheets laid on wood are nailed in the usual manner, while sheets laid on angle iron construction are fastened as explained in the

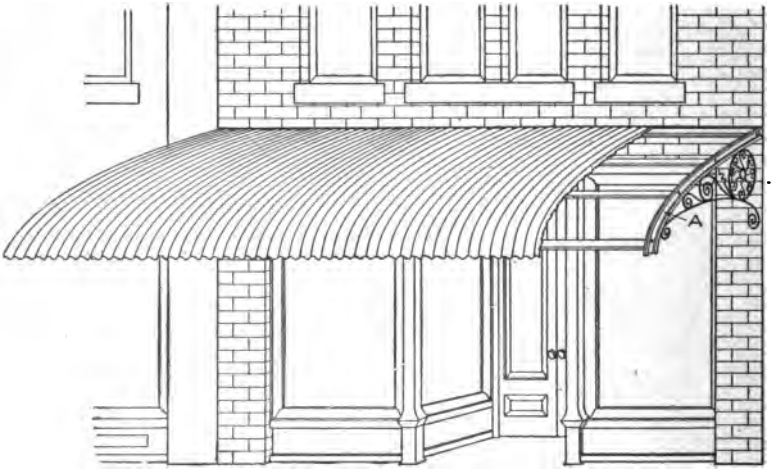


Fig. 254.

preceding sections. In Fig. 254 is shown an awning over a store laid on angle iron supports. In work of this kind, to make a neat appearance, the sheets are curved to conform to the iron bracket A.

INDEX

INDEX

The page numbers of this volume will be found at the bottom of the pages; the numbers at the top refer only to the section.

	Page
A	
Angles	110, 114
measurement of	114
Approximate measurements	275
Arches	274
Architectural drawing	213–332
definitions	224
exhibition drawings	270
importance of axes	225
instruments and materials	213
line drawing	221
measured work	273
practical problems in design	277
preliminary studies in architectural design	267
rendering in wash	243
sketching	270
water color hints	258
Armature end ring	50
Armature head	48
Armature punchings	49
Assembled cone gears	41
Attic framing plan	307
Attic plan	301
Axes in architectural drawing	225
limiting lines	231
B	
Back clutch pinion	26
Back tool post	38
Bars, shapes of	338
Basement plan	296
Bathroom	284
Beam compasses	82
Bevel gears for rolls on sheet bar and slab mill steam flying shear table	52
Binder arm for rope take-up	55
Blueprint reading	11–64
analysis of typical blueprints	24
general directions for	13
introduction	11
Blueprints	11
definition	11
importance of	12
process of making	11
reading	13
what blueprints should show	12
Blueprints analyzed	24
armature end ring	50
armature head	48
armature punching	49
assembled cone gears	41
back clutch pinion	26
back tool post	38
bevel gears for rolls on sheet bar and slab mill steam flying shear table	52
binder arm for rope take-up	55
center arm head	39
center rest assembly	35
center rest base	34
center rest top	33
check valve	58
cone gears	41
cross-feed connecting link	33
diamond tool post T bolt	33
down-feed worm	43
down-feed worm wheel	28
drawing-in bolt	36
end shield	47
face gear	42
field punching	50
geared mechanism for loom	57
gears used on 12-inch merchant mill	51

Note.—For page numbers see foot of pages.

	Page
Blueprints analyzed (continued)	
globe valve	40
intermediate shaft clutch	30
knee shaft clutch	37
miscellaneous mechanisms for looms	58
motor coupling of rod mill drive	54
plan of foundry building	63
pole piece lamination	51
roof truss	61
saddle adjusting lever	44
saddle nut	24
shaft-bearing pedestal	47
shuttle mechanism for loom	56
spindle	60
swivel table stud	32
top pulley bracket	44
wheel guard T bolt	32
work spindle slide	35
Bow pen	79
Bow pencil	79
Brushes	262
Building a house, various stages in	285
Butler's pantry	283

C

Cellar	284
Center arm head	39
Center rest assembly	35
Center rest base	34
Center rest top	33
Check valve	58
China closet	317
Circles	113
Closets	284
Colonial house	291
attic framing plan	307
attic and roof plan	301
basement plan	296
elevations	292
first-floor framing plan	307
first-floor plan	296
framing of front elevation	313
framing of side elevation	313
front and side elevations	301, 305
kitchen, pantry, and china closet	317
main cornice and dormer	317
Colonial house (continued)	
plans	292
plumbing	317
porch and front entrance	325
roof framing plan	313
second-floor framing plan	307
second-floor plan	298
sketches	291
staircase and fireplace details	327
trim on first floor	325
uniform titles for drawings	325
useful memoranda	292
window frames, detail of	319
Color combination	262
Colors	265
Compasses	76
Composition	277
Cone gears	41
Cones	117, 176, 177
Conic sections	119
ellipse	119
hyperbola	120
parabola	120
Contract, letting	289
Conventions used in mechanical drawing	22
Cornice	317
Corrugated iron roofing	384, 387
Corrugated iron siding	384, 392
Cross-feed connecting link	33
Cube, isometrics of	181, 184
Curbs, shapes of	339
Cycloid curve	121
Cycloidal curves	121
cycloid	121
epicycloid	122
hypocycloid	122
Cylinders	117, 175, 185

D

Design, theory of	277
Design of dwelling	281, 291
bathroom	284
butler's pantry	283
cellar	284
closets	284
dining room	283

Note.—For page numbers see foot of pages.

	Page
Design of dwelling (continued)	
hallway	281
kitchen	283
living rooms	282
number of rooms	281
practical example, colonial house	291
refrigerator	283
stairways	282
storeroom	284
Detail drawings	287
Development of surfaces	174
cone	177
general details of process	174
rectangular prism	176
regular triangular pyramid	178
right cone	176
right cylinder	175
truncated circular pyramid	179
Diamond tool post T bolt	33
Dimension lines	17
Dining room	283
Dividers	78
"Don'ts" in drafting	91
Dormer	317
Double-pitch skylight	344
Down-feed worm	43
Down-feed worm wheel	28
Drawing boards	214
Drawing-in bolt	36
Drawing instruments and materials	67, 88, 213
beam compasses	82
board	68
bow pen	79
bow pencil	79
compasses	76
dividers	78
erasers	70
how to hold	88
ink	80
irregular curve	82
paper	67
pen	79
pencils	69
protractor	81
scales	81
T-square	70
Drawing instruments and materials (continued)	
thumb tacks	69
triangles	72
Drawing paper	215
Drawing sheet sizes	18
Dwelling	
design of	281
practical example	291
stages in building	285

E

École des Beaux Arts, Paris, method of starting problem at	268
Elevations	225, 253, 269, 292, 301, 305
Ellipse	119, 171
End shield	47
Epicycloid curve	122
Erasers	70, 213
Exhibition drawings	270

F

Face gear	42
Field punching	50
Finish lines	20
Fireplace details	327
First-angle projection	58, 143
First-floor framing plan	307
First-floor plan	296
Flat extension skylight	344
Flat-seam roofing	369
Framing of front elevation	313
Framing of side elevation	313
Front elevation	301, 305, 313

G

Geared mechanism for loom	57
Gears used on 12-inch merchant mill	51
Geometrical definitions	109
angles	110, 114
circles	113
cones	117
conic sections	119
cylinders	117
lines	109
odontoidal curves	121
polygons	110

Note.—For page numbers see foot of pages.

	Page
Geometrical definitions (continued)	
polyhedrons	115
solids	115
spheres	118
surfaces	110
Geometrical problems	123
Globe valve	40
Graded tints	254
Ground line	148
H	
Hallway	281
Hipped skylight	344, 345, 346
Horizontal center line	15
Hyperbola	120
Hypocycloid curve	122
I	
Inclining of objects	158
India ink	80
Inking drawing	84, 244
Intermediate shaft clutch	30
Intersections	22, 166
planes with cones or cylinders	171
planes with planes	166
Involute curves	122
Irregular curve	82
Irregular surfaces	22
Isometric projection	181
applications of	184
blocks	185
box with cover	186
cube	181, 184
cylinder	185
framework	185
house	185
prism	188
pyramid	188
K	
Kitchen	283, 317
Knee shaft clutch	37
L	
Large work, methods of showing	19
Lettering	83, 196
forming	83
inking	84
penciling	201
size of letters	196
spacing	84
style	85
titles for working drawings	201
types of	196
Lights and shadows	237
Limiting lines	231
Line drawing	221
Line shading	20, 194
Lines	16, 20, 109, 155
dimension	17
finish	20
line shading	20
section	18
shade	20
true length of	155
working	16
Living rooms	282
M	
Materials, representation of	288
Measured work	273
approximations	275
arches	274
datum lines	273
elevation measurements	274
inaccessible portions	275
materials	273
Mechanical drawing	11, 67–211
geometrical definitions	109
geometrical problems	123
instruments and materials	67
lettering	83, 196
line problems	92
projections	141
Metal roofing	360, 364
Miscellaneous mechanisms for loom	58
Modeling architectural drawing	234
Motor coupling of rod mill drive	54
O	
Objects	
representation of	157
rotating and inclining of	158

Note.—For page numbers see foot of pages.

	Page
Oblique projection	191, 232
characteristics	191
comparison with isometric	191
Odontoidal curves	121
cycloidal	121
involute	122
Office buildings	290
Ornament	280
Orthographic projection	141
definitions	141
development of surfaces	174
drawing	147
ground line	148
intersections	166
methods of	144
practical problems in	151
projection lines	148
representation of objects	157
rotating and inclining of objects	158
rules of	149
true length of lines	155
P	
Pan colors	258
Pantry	283, 317
Paper	262
Parabola	120, 173
Patterns for skylights	338, 346
Pencils	69, 79, 213
Pens	79
Perspective drawing	269
Perspective studies	269
Plan of foundry building	63
Plans	224, 254, 269, 292, 296
Plumbing	317
Pole piece lamination	51
Polygons	110
quadrilaterals	112
triangles	111
Polyhedrons	115
prisms	115
pyramids	116
Practical problems in design	277
colonial house	291
design of dwelling	281
notes on theory of design	277
office buildings	290
Practical problems in design (continued)	
stages in building house	285
Preliminary line problems	92
Preliminary studies in architectural design	267
Prisms	115, 176, 188
Projection lines	148
Projection rules	149
Projections	15, 141
isometric	181
oblique	191
orthographic	141
Protractor	81
Pyramids	116, 178, 188
Q	
Quadrilaterals	112
R	
Reduced scale of drawing	19
Refrigerator	283
Rendering	243, 253, 266
Representation of objects	157
Roof framing plan	313
Roof mensuration	365
Roof plan	301
Roof truss	61
Roofing	360
corrugated iron	384
flat-seam	369
forms of	364
roof mensuration	365
standing-seam	379
tools required	365
Rotating of objects	158
Rubbings	275
S	
Saddle adjusting lever	44
Saddle nut	24
Scale	81, 216, 278
School of Fine Arts, Paris, method of starting problem at	268
Second-floor framing plan	307
Second-floor plan	298
Section lines	18

Note.—For page numbers see foot of pages.

	Page
Sections	224, 254
Shade lines	20
Shading, line	20
Shadows	234
Shaft-bearing pedestal	47
Sheet metal work	335–394
roofing	360
skylight work	335
Shop tools	338
Shuttle mechanism for loom	56
Side elevation	301, 313
Single picture views	23
Single-pitch skylight	343
Sketch elevations	269
Sketch plans	269
Sketches	285, 291
Sketching	270
Skylight work	335
bars, shapes of	338
construction	335
curbs, shapes of	339
patterns	338
shop tools	338
styles of skylights	343
Skylights	343
double-pitch	344
flat extensions	344
hipped	344, 345, 346
single-pitch	343
Solids	115
Spheres	118
Spindle	60
Staircase details	327
Stairways	282, 327
Standing-seam roofing	379
Storeroom	284
Surfaces	110
Swivel table stud	32
Symbols used in mechanical drawing	21

T

T-square	70, 215
Tapes	273
Theory of design	277
composition	277
criticism	280
ornament	280
scale	278
Third-angle projection	59, 142
Thumb tacks	69
Tinted papers	215
Titles for drawings, uniform	325
Top pulley bracket	44
Tracing cloth	216
Tracing paper	216
Triangles	111
Triangles (instrument)	72, 215
True length of lines	155
Tube colors	258

V

Vertical center line	15
Views of object	13, 141
interrelation of	15
method of obtaining	13
number needed	15

W

Wash, rendering in	243
materials	243
method of	244
Water color hints	258
brushes and paper	262
combination of color	262
manipulation	262
primary, secondary, and complementary colors	265
rendering	266
sketching	267
tube and pan colors	258
Wheel guard T bolt	32
Window frames, detail of	319
Work spindle slide	35
Working drawings	11, 286
Working lines	16

Note.—For page numbers see foot of pages.

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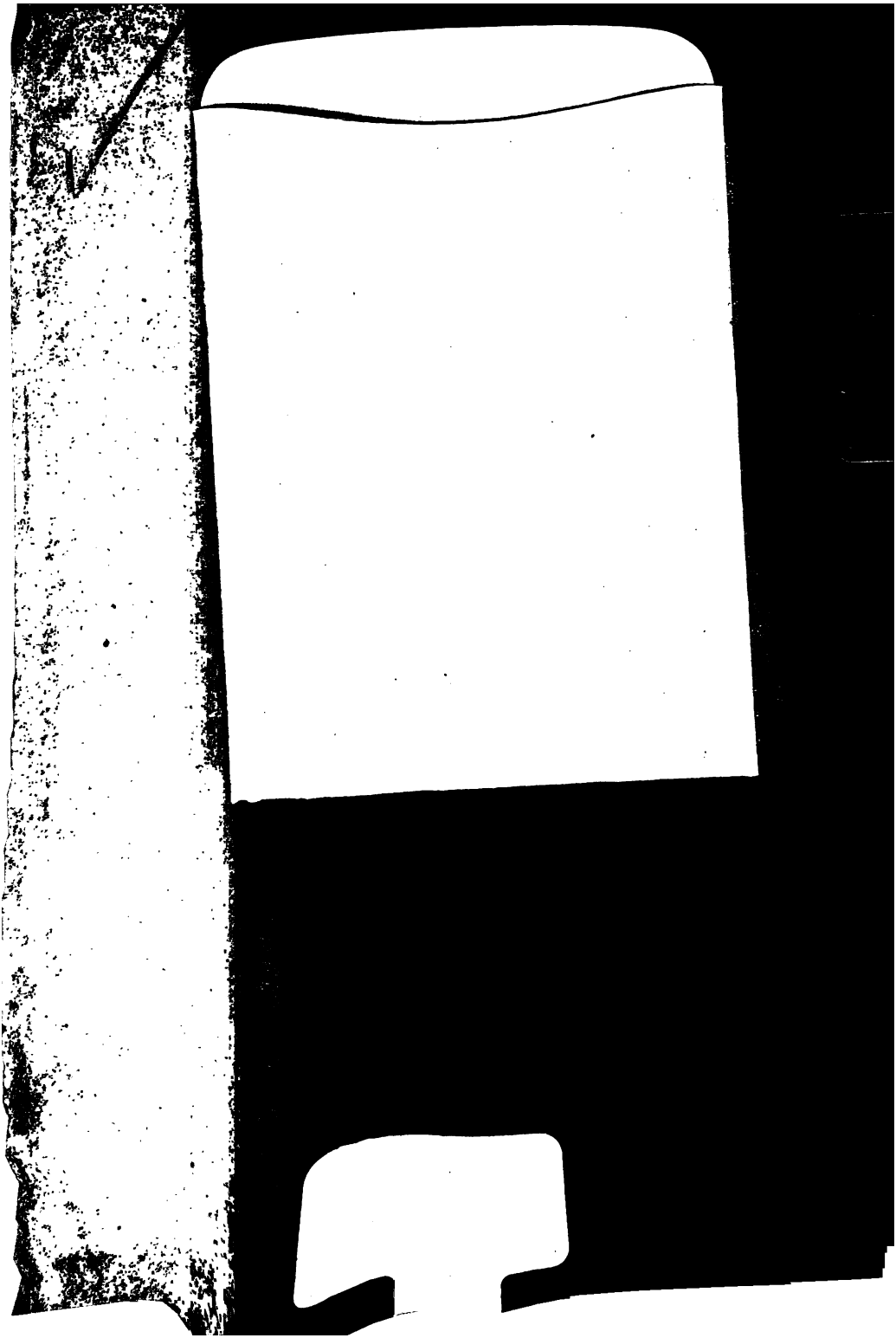
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